Time of Day, Alcohol and Driving-related Performance

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1. ABSTRACT

The performance inhibiting effects of alcohol on the type of the psychomotor skills employed during driving are well documented. Circadian rhythmicity is known to impact independently on both driving related performance and the physiological effects of various drugs. The question with which this study is concerned is whether the effects of alcohol on driving related performance are constant across time, or variable according to the phase of the circadian cycle at which the alcohol is ingested and the task performed. Research specific to circadian mediation of alcohol related performance is sparse. Few studies (Reinberg, 1992) have examined multiple time conditions using a within groups repeated measures experimental design. In susceptibility to time of day performance fluctuation as in the extent of alcohol effects, the nature and duration of the task are important mediates. Significant alcohol time of day interaction has been demonstrated in the afternoon relative to evening performance on medium length cognitive, visual and auditory vigilance tasks. The present study compares alcohol relative to nil alcohol performance on a battery of brief psychomotor tasks at 0900, 1300, 1800 and 0100 hours. Sixteen male non-combatant soldiers with a mean age of 29 acted as subjects in a within groups repeated measures design. A dose of 2.26 ml of (37%) alcohol per kg of body weight was administered with a light meal to attain a blood alcohol level approximating 80mg/100 ml of blood, the legal maximum concentration for a full license holding New Zealand driver (Ferrimond, 1990). ANVOA's were calculated in respect of tracking accuracy, lag and reaction time measures. Overall tracking accuracy as indicated by mean error measures was significantly effected by alcohol. The impact of alcohol on lag varied with the level of task unpredictability, with non-preview tracking tasks more susceptible to the performance inhibiting effects of alcohol. No significant alcohol x time of day interaction was recorded for mean error, lag or reaction time measure on any of the seven tracking tasks under analysis of alcohol relative to nil alcohol performance across the four times of day. Findings are discussed firstly, in terms of their implications for road safety, and secondly, in contrast with previous chronobiological research, pertaining to the types of tasks, conditions and individual factors which may be more or less susceptible to circadian performance variation and alcohol x time of day interaction.

Time of Day, Alcohol and Driving-related Performance

2. INTRODUCTION

A substantial body of research attests a causal connection between alcohol consumption and impairment of the sensory and psychomotor skills associated with driving an automobile. Circadian rhythmicity is known to impact independently on both driving related performance and the physiological effects of various drugs. The question with which this study is concerned is whether the effects of alcohol on driving related performance are constant across time or variable according to the phase of the circadian cycle at which the alcohol is ingested and the task performed.

2.1. The Magnitude of the Drink-Drive Problem

In 1991 650 persons were killed on New Zealand roads and a further 16.766 injured. Young men between the ages of 15 and 24 accounted for 35.5% of the former figure and 38.9% of the latter (Ministry of Transport cited in New Zealand Official Yearbook, 1993). Motor vehicle accidents associated with excess breath alcohol each year place considerable strain on finite health, justice and social service resources. A disproportionate amount of the annual traffic control vote is consumed in apprehension and processing of drunk drivers. Justice Department Court statistics for 1990, report a total of 129 charges of driving under the influence of drink or drugs causing death, and a further 242 of causing injury. The same source cites 21159 charges (19,678 convictions) of driving with excess breath alcohol. This figure represents 10% of the total traffic related convictions for the period.

2.2. The Effects of Alcohol on Driving Related Performance

A substantial body of research attests a causal connection between alcohol consumption and impairments of the various sensory and psychomotor skills associated with driving an automobile (Vuchinich & Sobell, 1978; Gowen and Ranney, 1988; Kearney and Guppy, 1988;Lyon et al, 1973; Moskowitz et al, 1985). What is also evident from the literature is that the alcohol/driving performance relationship is complex, influenced by numerous mediating factors. Age, sex (Newlin, 1986 & 1989), alcohol tolerance/sensitivity (Beirness & Vogel-Sprott, 1984; Shapiro & Nathan, 1986), expectancies (Nagoshi et al, 1992; Haubenreisser & Vogel-Sprott, 1987), fatigue (Landgrave, et al, 1989-90), stress, food intake (Gawron et al, 1988), driving experience (Sdao-Jarvie & Vogel-Sprott, 1992), metabolic rate, substance use (Lyon et al, 1975) and personality variables (Donovan & Marlatt, 1982; Stacy et al, 1991) have each been identified as possible mediators in the extent to which alcohol effects driving performance (Chan, 1987).

2.3. Circadian Rhythmicity

2.3.1. Biological Rhythmicity

Almost all aspects of biological functioning follow a rhythmic pattern. Most notably in consideration of alcohol effects, variations occur in body temperature (Kleitman 1963, Froberg et al, 1975, Akerstedt et al, 1977, Lille and Cheliout, 1982) blood circulation, liver and kidney function and metabolic rate. Some diurnal cycles are endogenous while others depend on environmental cues and regular sleep wake routines to maintain rhythmicity. Irrespective of origin, stable environmental cues maintain rhythmic consistency within species across time.

2.3.2. Circadian Rhythmicity in Performance

Arousal and body temperature typically begin their ascent around the beginning of the activity cycle, increase throughout the morning, both dip slightly post-lunch (Anderson et al, 1991, Colquhoun in Webb, 1982) and ascending in the evening before plunging to an extreme low after midnight. Industrial psychological research has consistently demonstrated circadian performance patterns across a range of tasks (Rogers, et al, 1989; Monk & Leng, 1982).

2.3.3. Circadian Mediation of Drug Effects

Circadian rhythms have been found to mediate both the therapeutic efficacy and toxicity of a variety of drugs (Lemmer & Labrecque, 1987). Cardosos et al (cited in Moore-Ede, Czeisler & Richardson, 1983) found the lethality of a high drug dosage to very between 15 and 74 percent in a population of mice, depending on the phase of the circadian cycle at which the toxin was administered.

While circadian variations in physiological functioning and various aspects of psychomotor and cognitive performance are supported by substantial mutlidisciplinary literature, time of day is often not given due consideration in psychological research (Hobbs & Goldenberg, 1987) or subsequent applications of research findings.
In a review paper focusing on various factors which contribute to automobile accidents either in conjunction with or independent of alcohol Chan (1987) comments that "most pharmacokinetic studies have ignored a possible circadian variation of the metabolic rate of ethanol". Notwithstanding the "most" which don't, there are a few studies which have considered time of day as a potential variable in the extent to which alcohol affects driving related performance.

Pursuant to a surprisingly low alcohol induced impairment on a cognitive task (Jones and Vega, 1972) performed in the evening, Jones (1974) undertook a follow-up study to determine whether circadian rhythmicity might have accounted for unexpected result. Using a subject group matched as nearly as possible to the participants of the original study, Jones replicated the original study administering alcohol or alcohol placebo in an afternoon testing schedule. The rate at which alcohol is metabolized was also scrutinised for circadian variation. Results revealed a significant drug/time of day interaction on alcohol elimination rate and a nonverbal cognitive task. No significant difference was recorded in peak BAC, duration from ingestion to BAC peak or alcohol absorption rate. Jones comments that the "normal circadian variation in cognitive performance" may be reversed under alcohol. However, he also advocated the application of within groups repeated measures designs across a range of cognitive and psychomotor tasks to test the generalizability of his findings.

Recent research in Britain has focused on alcohol induced exacerbation of what the authors (Horne & Gibbons, 1991) describe as the "circadian propensity for sleepiness in the early afternoon". In an investigation into the effects of alcohol early afternoon and early evening on vigilance and sleepiness, Horne and Gibbons (1991) administered placebo, 47.4 ml and 94.8 ml of alcohol with food to a group of eight women at 1300 and 1830 hours in a double-blind randomised repeated measure design. Once blood alcohol concentration had reach the predetermined level (<5, 35 and 70 mg alcohol per 100/ml of blood respectively) subjects performed a simple auditory vigilance task for a one hour period. Results revealed a significant "dose x time of day interaction" for both reaction time and number of correct responses. A small quantity (47.4 mls) of alcohol consumed in the early afternoon was found to have a performance inhibiting effect approximating that produced by twice that amount taken early evening.
A subsequent study (Horne and Baumber, 1991) investigated time of day as a variable in alcohol induced impairment of performance on a monotonous simulated driving task. Mean following distance and following distance variability showed both a significant alcohol induced performance impairment and a time-of-day/alcohol interaction.

While the British women who participated in the Horne and Baumber(1991) and Horne and Gibbons (1991) studies may be more accustomed to the "pub lunch" phenomena than their New Zealand counterparts, evening is the time of day when alcohol is more typically consumed. Thus Horne et al's apparent circadian phase/alcohol induced performance impairment interaction may be a compensation effect associated with a conditioned alcohol expectancy. Performance may have been more effected by alcohol at 1300 than 1800 hours simply because subjects are less accustomed to alcohol consumption at lunchtime than in the early evening. In order to differentiate alcohol expectancy effects from circadian phase proper, the testing schedule of the current study includes a beverage consumption (alcohol and nil alcohol) and testing session at 0900 hours.

Nine am provides a body temperature phase peak at a time of day at which few individuals will have significant alcohol consumption experience. If alcohol induced performance impairment is less at this time of the day than is evident at later trough phases of the cycle the results may be interpreted as supportive of a circadian body temperature involvement. Conversely if alcohol affected subjects perform less well during a morning phase peak than a late nigh phase trough a conditioned alcohol/time of day expectancy may be indicated.

In a small hospital based study, Reinberg (1992) investigated ethanol effects across a range of physiological and psychological variables at four times of day (0700, 1100, 1900 & 2300 hours). Six subjects completed self ratings on scales of inebriety, physical vigour, and mood, performed ten minute addition, paced counting and co-ordination tasks in addition to a series of physiological measures including, heart rate, blood pressure, expiratory flow, oral temperature, grip strength, plasma and urinary variables. Self-rated inebriety was found to peak at 2300 hours and coincide with worst performance on paced number addition and eye-hand co-ordination tests. Neither self rated physical vigour nor grip strength differed significantly under alcohol relative to control values irrespective of time of day. Both systolic blood pressure and performance on the tempo counting task were affected by alcohol but no dosing time variation was evident. The impact of ethanol on plasma cortisol levels did not reach statistical significance at 1100 and 1900 hours, but produced significant changes at both 0700 and 2300 hours - a decrease at the former and an increase at the latter time relative to control values. Interaction effects reached significance between blood-ethanol and the addition test. Self rated inebriety interacted at a significant level with both the number addition and the eye-hand skill test.

2.4. Individual Variables

A number of individual variables have been found to independently mediate either the circadian phase/performance or alcohol/performance interactions, several of which have implications for the current study.

2.4.1. Morning/Evening Preference

Harma & Ilmarinen et al (1988) noted that individual adaptation to shift work tends to be more often associated with personality than physiological differences. Morning/ evening preference has been found to be associated with the timing of both body temperature and performance peaks (Horne & Ostberg, 1977; Anderson et al , 1991). Horne and Ostberg report that the body temperature of morning types is higher at waking and peaks around an hour earlier than that of evening preferring counterparts. To minimise the confounding potential "morning/evening" preference the Horne and Ostberg "Morningness/Eveningness" Scale was administered to all participants of the present study to ensure balance.

Research by and subsequent to Horne and Ostberg (1977) has found individual preference for morning or evening activity to be associated with distinct differences in body temperature acrophase and performance cycles. Failure to control for time of day preference via random allocation of subjects in a between groups design casts doubt on the apparent isolation of circadian rhythmicity in a brief psychomotor task.

2.4.2. Physical fitness

Physical fitness is reported by Atkinson, Coldwell and Reilly (1993) to correlate with higher body temperature amplitude, which in turn has been associated with increased tolerance to irregular work schedules. Circadian troughs in subjective arousal and left grip strength were significantly less pronounced in physically active subjects. Subjects in the present study had regular exercise regimes and were subject to annual fitness test.

2.4.3. Locus of Control in Subjective Assessment of Intoxication.

Locus of Control describes the relative weight the individual apportions to internal and external factors as determinants of life events. Reinberg (1992) reports a statistically significant interaction between aspects of cognitive and psychomotor performance and self-rated inebriety. Locus of control in turn influences the accuracy of inebriety estimation. Subjects typically fare poorly on self report measures of intoxication based on introspective subjective assessment (Marlatt & Rohsenow, 1980, cited in Rohsenow & Marlatt, 1981; Beirness, 1987). Assessments based on external cues (number of drinks/duration of drinking) tend to return more reliable estimates of intoxication (Jaccard & Turrisi, 1987). Subjects with internal locus of control tend to weight internal cues more heavily than external cues in assessing their level of intoxication and are more likely than their "external" counterparts to underestimate alcohol induced impairment and overestimate their driving ability (Jaccard & Turrisi, 1987).

2.5. The Present Study

In summary we know that alcohol impedes performance on many of the psychomotor tasks employed during driving. We know also that circadian rhythmicity impacts independently on both driving related performance and the physiological effects of various drugs. The question with which this study is concerned is whether the effects of alcohol on driving related performance are constant across time or variable according to the phase of the circadian cycle at which the alcohol is ingested and the task performed.

Pursuant to the recent work of Reinberg who reports an alcohol/time of day interaction across a range of physiological and performance measures using a six subject within groups repeated measures design. The current study employs a larger sample (n=16) in a naturalistic setting (in contrast to Reinberg's 30 hour hospital admission), and substitutes a battery of brief psychomotor for the number addition, paced counting and eye-hand co-ordination tasks used in the Reinberg study.

2.5.1. Potential Implications for Road Safety

The New Zealand Police have authority under Section 58A of the Transport Amendment Act (1978) to breath test any full licence holding driver suspected of operating a motor vehicle with a blood alcohol concentration in excess of 80 mg per 100 ml (400 mg of alcohol per litre of breath). Education and legislation work together to reinforce the anti drink-drive message. Information currently in circulation as to safe alcohol consumption for the intending driver presumes the effects of a given quantity of alcohol remain constant across time - an assumption which may prove misguided. Most drivers are aware of the perils of taking the wheel after having consumed a bottle of wine in an evening, few of us however, would consider our driving equally impaired by just two glasses of the same vintage in the early afternoon.

Such issues are particularly relevant in the light of an increasing incidence of alcohol as a factor in daytime automobile accidents in this country. If the effects of alcohol on driving performance are found to vary across time of day, drivers could be alerted to periods of increased susceptibility to deleterious effects. At the very least, driver, educators and legislators should be made aware that breath and/or blood alcohol concentrations alone may not be a reliable indicators of the individuals capacity (or otherwise) to drive safely.

2.5.2. Circadian Effects, Nature and Duration of Task

As with the alcohol/performance relationship, the extent to which diurnal fluctuations in arousal impact on performance varies according to the nature of the task.

Sensorimotoricity, information processing, decision making, perception and attention have each been found to follow a performance curve approximating the circadian temperature cycle (Knauth, Kiesswetter & Rutenfranz, 1981, Daniel and Potasova, 1989; Colquhoun in Webb, 1982). In addition to the nature of the activity, task duration has been cited as a variable in the extent to which performance is influenced by diurnal variation. A task length threshold in susceptibility of performance may be important with respect to post-lunch effects is suggested by Smith and Miles (1986). Blake (1971) likewise argues that simple prolonged boring tasks are the more susceptible to diurnal performance fluctuations. Consistent with Blake (1971), Rogers et at (1989)have identified early morning performance speed and accuracy deficits across a range of moderate to long (10 to 26 minutes) tasks incorporating sustained attention, tracking, reaction speed, visual, auditory and complex vigilance.

Evidence exists that even short duration tasks may show performance variation across time of day. Naitoh, Englund & Ryman (1985) report statistically reliable circadian rhythms in several comparatively brief vigilance and reaction tasks. Including a six minute alternation key tapping task, a two minute matched letter search task and a six minute four choice serial reaction time task. In a between groups design Payne (1989) examined proficiency on three one minute mirror tracking tasks across nine time points between 0900 and 1800 hours. Payne describes a "significant linear trend" with tracking accuracy declining across the morning from a 0900 high, making a dramatic recovery at 1400 hours before falling progressively to a 1700 hour low. While these results are suggestive of circadian performance variation in a short duration psycho-motor task, validity is seriously threatened by subject preferential selection of time condition.

2.5.3. Driving Simulation

In the artificial laboratory situation "driving" is typically dissected into component tasks, one or more of which are examined under alcohol relative to alcohol free or placebo conditions. While it is generally acknowledged that off road simulation does not adequately replicate the real life driving situation it does provide a practical ethical means of measuring changes in various driving related tasks under various experimental manipulations.

The nature of the simulation task is a major determinate of the impact of alcohol on performance. The driving assessment apparatus adopted for use in this study was developed by Dr Richard Jones of Christchurch Hospital's Department of Medical Physics and Bioengineering and is routinely used by Christchurch Hospital staff in off-road assessment of driving related skills. The test battery includes seven brief psychomotor tasks each of which yielded measures of tracking accuracy and lag (ms delay between target and response). The efficacy of the computerised assessment regime in measurement of aspects of driving related performance has been tested and its relevance on- road driving skills established.

2.5.4. Alcohol Placebo

Alcohol placebo was not used in the present study due to difficulty with maintenance of the deception at other than low levels of orally ingested alcohol. A review of double blind studies by Rohsenow and Marlatt (1981) found both recipients and administrators tended to accurately discriminate alcoholic from placebo beverages at other than low alcohol doses. Lukas, Mendelson and Benedikt (1986) further note that subjects tend to actively search for clues of deception.

The impact of alcohol placebo (relative to alcohol) is mediated by sex, various personality characteristics, conditioned alcohol expectancies and the nature of the task or function under investigation. Alcohol expectancy/conditioned response in male subjects has been found to run in a direction antagonistic to alcohol (Newlin, 1985; Brown, Goldman, Inn and Anderson, 1980; Rohsenow and Marlatt, 1981). That is, administration of placebo to moderately experienced drinkers may result in improved performance relative to baseline (Beirness & Vogel-Sprott, 1986, report this phenomena in a pursuit tracking task) artificially inflating performance under placebo relative to alcohol.

2.5.5. Specific Objectives

The primary purpose of this investigation is the search for circadian variation in the extent to which alcohol effects driving related performance. The null hypothesis therefore being that the deleterious effects of alcohol on driving related performance are constant across time. Should the null hypothesis be rejected, differentiation of physiological circadian phase performance variation from alcohol expectancy effects is a second objective.

Research specific to circadian mediation of alcohol related performance is sparse. Those studies which have examined the diurnal performance/alcohol interaction have typically used between groups design (Horne & Baumber, 1991; Horne and Gibbons; Jones, 1974) and limited the comparison to two time conditions (Horne & Baumber, 1991; Horne & Gibbons 1991; Jones 1974). Reinberg (1992), in contrast, conducted a within groups repeated measures exploration of four time conditions, but using a sample of only six subjects under highly artificial hospital (inpatient) conditions.

This lack of guidance from a sparse literature coupled with the number of potentially confounding variables largely dictate the experiment design, methodology and mode of analyses employed in the current study. Replication or extension of the findings of the few published studies have been included as specific objectives in the current study as follows:

1. Estimation of possible circadian performance variation in Jone's (1983, 1986) driving-related psychomotor tasks across four times of day independent of alcohol. Are the various sensorimotor task influenced by alcohol and, if so, are some more sensitive than others.

2. Comparison of alcohol relative to nil alcohol performance at 1300 and 1800 hours after Horne and Gibbons (1991) and Horne and Baumber (1991). Is the significant alcohol/time of day interaction reported by these authors able to be replicated using male subjects and a battery of brief tracking tasks.

3. Addition of 0900 and 0100 hour sessions to the Horne et al (1991) testing schedule in an endeavour to determine whether any time of day variation is explicable in physiological or expectancy terms. Is the significant alcohol/time of day interaction reported by Horne et al a function of the post lunch dip or a simple case of alcohol having a greater impact at a time of day not typically associated with its consumption.

4. Independent analysis of performance at 0900 and 0100 hours under alcohol relative to nil alcohol conditions. In contrast of a morning body temperature ascent at a time not traditionally associated with alcohol consumption with a temperature trough approximating tavern closing time.

5. Comparison of alcohol relative to nil alcohol performance on a battery of brief psychomotor tests across four times of day in search of diurnal variation in the extent to which alcohol effects driving related performance.

3. METHODS

3.1. Constraints

The contribution made by the New Zealand Army in the form of a venue and access to potential participants was substantial. A comparable subject population both willing and available for alcohol administration across four times of day and night would be extremely difficult to secure in a non-military context. Furthermore availability of an on-base testing venue negated various ethical and practical issues around security, safety and transport post-alcohol consumption.

The New Zealand Army is a highly mobile population. By late April 1994 with military commitment increasing and subject availability looking progressively less promising a decision was made to split the subjects required by the study into two groups, proceed with the first sample and accommodate the balance as they became available. Testing of the first group of nine subjects was completed in late August 1994 yielding seven sets of viable data. Access to subjects however worsened with New Zealand's increasing involvement in military exercises both national and international. When in late November access to subjects for the necessary duration was unable to be guarantied by the small unit who originally committed to the project a camp wide call for volunteers was issued. Volunteers were eventually solicited from Army Band ranks and testing was completed in early May 1995. Both groups were subject to the same procedure, both tested over autumn and winter months on New Zealand Standard Time.

3.2. Experimental Design

A within groups repeated measures design is employed in the current study to ensure the many individual personality and alcohol related variables cited in the introduction as potential mediates of alcohol effects and driving performance are held constant across test times and conditions.

3.3. Subjects

The armed forces provided an accessible homogenous, disciplined and highly motivated subject group. All participates were in good health, had regular sleep/wake patterns and exercise regimes, with physical fitness levels at a minimum military criteria.

Sixteen male non-combatant soldiers (drivers, caterers and bandsmen) from the New Zealand Army's Burnham Military Camp volunteered to participate in the study. Subjects were tested in two distinct groups. The first consisted of caterers and drivers, the balance recruited from Army band ranks. The subject group had a mean age of 29 (SD 6) and mean clothed weight of 82.9 kg (SD 7.9). All participants were social drinkers, none reported any medical condition likely to be exacerbated by alcohol consumption.

3.4. Preliminary Data Collection

Potential participants each received a folder containing a brief overview of the study (Appendix 1.), description of the level of participation required, the preliminary information sought, alcohol dose to be consumed and task to be performed. Informed consent was given by each subject.

Prospective participants were asked to:

> Complete the Horne and Ostberg "Morningness/Eveningness" Scale, a 19 item questionnaire designed to differentiate morning from evening performance preference (Appendix 3.)
>
> Complete the "Rotter Internal/External Locus of Control Inventory" (Appendix 4), a 29 item questionnaire which quantifies the extent to which the individual considers situational and personal factors determine life events.
>
> Agree for their weight to be taken and recorded to enable beverage preparation on a ml/kg body weight basis.

3.5. Apparatus

The apparatus used in this study was developed by Dr Richard Jones of Christchurch Hospital's Department of Medical Physics and Bioengineering and is routinely used by Christchurch Hospital staff in off-road assessment of driving related skills. In preliminary evaluation (Jones, 1992) quantitative assessment of fitness to drive in a 54 patient sample as determined by performance on the computerised test battery alone matched overall recommendations (including clinical appraisal of medical conditions, physical, cognitive and insight deficits, and discretionary on-road assessment) in 96% of referrals. The efficacy of the computerised assessment regime in measurement of aspects of driving related performance has thus been validated and its relevance on-road driving skills established.

The apparatus is ideal for the purposes of the current study in that the error measures are sensitive to slight variations in performance while the level of task difficulty, even in the more simple pursuit tasks, sufficient to preclude error free performance.

The testing equipment consisted of a steering wheel and two visual display units connected to a personal computer. The subject was seated on an armless chair in front of a steering wheel and visual display unit, adjacent to the second screen (i.e. assessors) such that verbal instruction could be clearly received by the driver without visual distraction. The subject's seat could be moved forward or back to accommodate individual preference and variations in subject size. A moving target and arrow shaped cursor were displayed on the screen viewed by the subject. On each individual trial required the subject to track a paced target, responding to variations in its position as quickly and accurately as possible. Levels of task difficulty varied from the relatively easy 70 second previewed sine tracking task, to a two minute divided attention task combining tracking and reaction speed. Each testing session included a battery of seven short tracking tasks, four of 70 and three of 120 second duration. Each of these are described in detail below. The seven tasks were undertaken sequentially with 30 second inter-test interval and each testing session taking around 15 minutes in total.

3.6. The Seven Test Battery

3.6.1. Non-preview Tracking Tasks (Sine and Random)

The test battery included two 70 second sine tracking tasks in which a straight vertical line moves laterally across the video screen. The lateral motion of the target (a vertical line) was predictable in the "sine" version of this test, while erratic and unpredictable in the random derivation. In each case the driver was required to track the target laterally keeping the point of the cursor arrow on the line as accurately as possible. While these two tests are derivatives of the same task, increased difficulty of tracking the erratic motion of the random version is reflected in larger error scores.

3.6.2. Preview Tracking Tasks (Sine and Random)

In the two 70 second previewed tracking tasks, the target appeared as a continuous wave travelling down the "drivers" monitor at an even pace, again each task required accurate pursuit of the descending curve with the arrow tip. The sine version of the previewed task was symmetric in its wave form, the random derivation irregular. These tasks had identical targets to the Non-preview derivations described above and differed only in that a visual preview of the target waveform was displayed.

3.6.3. Step Tracking

The non-preview step task requires the subject to respond as quickly as possible to unpredictable lateral movement. In this 120 second test a vertical line jumps variable distances left or right, pausing several seconds before resuming a central position. Because both the direction and distance at which the target appears are unpredictable the driver is unable to profit from anticipation.

3.6.4. Step Tracking with Preview

The preview step tracking task consists of a series of vertical and horizontal lines of varying lengths joined by 90 degree angles to form an irregular stepped pattern. The steps move down the video screen at a constant pace and the driver is required to maintain the arrow point on the line as much as possible. Sharp and precise lateral movement is required in response to horizontal step orientations. This test is a preview version of the step tracking task described above.

3.6.5. Combination Tracking

Combination tracking integrates random preview and non-preview step tracking. In this 120 s task the driver is required to track an irregular wave pattern which descends through the video screen at a constant speed. The wave pattern periodically disappears and is replaced by a vertical line at which time the "driver" is required to move the arrow point onto the new target as quickly as possible. Similarly when the vertical stimulus vanishes and the wave pattern reappears the subject must quickly resume random tracking. The timing and location of the vertical target's appearance are unpredictable and may require the driver to change direction and/or travel some distance. This task incorporates tracking, reaction speed, sustained and divided attention components. Its relative level of difficulty is reflected in subjects lag and mean error scores.

3.7. Performance Measures

Scores are expressed in error terms such that the higher the score the poorer the performance. Two independent measures were analysed for each of the seven tracking tasks:

mean error	- being the average horizontal distance between arrow point and target in mm.
mean lag	- the average delay between response and target in ms.
reaction time	- expressed was analysed for both the steps out and back from the central position on the Non-preview Step Tracking task.

Additional measures of ballistic reaction time were available for the non-previewed step tracking task. Reaction speed expressed in terms of millisecond response were analysed for both the departure and return of the stimulus to the central position .

3.8. Procedure

3.8.1. Administration of Alcoholic and Non-alcoholic Beverages

Subjects were asked to fast for 4 hours and refrain from alcohol consumption for a minimum of 12 hours prior to each testing session. Alcoholic and non-alcoholic beverages were prepared in full view of subjects. On each occasion subjects were aware of whether the beverage was alcoholic or otherwise. Use of alcohol placebo was considered but rejected due to difficulty with maintenance of the deception at other than low levels of orally ingested alcohol. A dose of 2.26 ml of (37%) alcohol per kg of body weight was administered to attain a blood alcohol level approximating 80mg/100 ml of blood, the legal maximum concentration for a full license holding New Zealand driver (Ferrimond, 1990).

Vodka was selected due to its relative purity and mild flavour. Beverage for the nil alcohol condition consisted of an equivalent volume of tonic water (i.e. 2.26 kg per kg plus 150%). A dash of lime was added to both alcoholic and non-alcoholic beverages to improve palatability.

Administration procedure modelled that described by Horne and Gibbons (1991). One part vodka (37% alcohol by volume) diluted with 1.5 parts of tonic water consumed over 20 minutes with a filled bread roll (12 g bread roll filled with a slice of cold meat, and salad). A pilot study by Horne and Gibbons (1991) examined the respective effects of heavy, light or no food on blood alcohol under a constant dose. In all conditions alcohol was consumed over 20 minutes, peak blood alcohol concentrations were found 10 minutes post consumption before declining over a two hour period. Alcohol only consumers had both the highest peak blood alcohol concentration and the steepest decline. Conversely, peak blood alcohol concentrations of heavy meal consumers reached only half those of their light meal counterparts and declined only slightly over time. Subjects in the light meal condition attained a peak blood alcohol concentration slightly lower than the alcohol only group, plateaued briefly before falling into a steady but gradual decline. The "light meal" condition was preferred by Horne and Gibbons (1991) and adopted for the present study.

Alcohol was consumed over a 20 minutes followed by a 10 minute waiting period prior to commencement of performance testing (again after Horne et al 1991). This relatively short waiting period was selected firstly to allow completion of performance testing before blood alcohol concentration declined and secondly to avoid potential confound in the form of variable tolerance during the descending plasma ethanol curve. Under an acute dose of alcohol, tolerance enables performance recovery at a higher level on descending relative to ascending blood alcohol concentration (Haubenreisser and Vogel-Sprott, 1987).

3.8.2. Testing Venue

The testing venue for each of the two subject groups was their respective company headquarters. Both subject groups consumed the food and beverage in familiar common room space before proceeding to the testing area adjacent.

A priming venue already associated with social interaction and alcohol consumption was selected in an attempt to reduce the risk of tolerance developing as the testing environment progressively became a conditioned cue for alcohol administration (Beirness and Vogel-Sprott, 1984; Bennett and Samson, 1991). A testing occasion typically included two or three subjects with the latter part of the beverage consumption/waiting period of earlier scheduled subject overlapping with the next subjects beginning preparation. Each of the two subject groups were workmate cohorts. Overall pre-test preparation was a relaxed affair with alcohol administration taking place with familiar persons in familiar surroundings.

While pre-existing conditioned cues associated with the cohort and venue would obviously not attenuate the effects of alcohol expectancies in the nil-alcohol condition such expectancies should at least remain constant across the time series.

3.8.3. Times of Testing and Test Protocol

Subjects were tested across four time conditions: 0900, 1300, 1800 and 0100 hours. The testing schedule incorporated the two session times used by Horne and associates (1991) at 1300 and 1800, with two additional sessions. The first at 0100 hours during the overnight body temperature trough and a second at 0900 hours during the mid-morning ascent.

A mid-morning (0900 hour) administration is necessary to differentiate body temperature related performance variation from alcohol expectancy effects. The 0900 hour session provides an ascending body temperature curve at a time of day not typically associated with social alcohol consumption. Conversely, the early morning condition (0100 hours) combines a temperature phase trough with the time at which many are making their way homeward after alcohol consumption.

Each of the 16 subjects completed the seven test regime at each of these four times of day twice, influenced by alcohol on one occasion and once alcohol free. The alcohol free performance provided a chronogram against which alcohol impaired performance could be contrasted.

The large number of experimental conditions relative to the number of subjects precluded absolute balance of testing order. Latin square sequencing was considered inappropriate for this type of repeated measure time series design. While it does ensure balance across starting conditions, the rolling sequence of the Latin square would establish an identical order of progression through the time/alcohol conditions for each subject, albeit from a staggered start point, and run the risk of a cumulative practice effect. Start conditions were randomly assigned such that two subjects started at each of the eight time x alcohol dose combinations (4 time conditions x 2 alcohol levels). and testing sequences randomised thereafter.

Because of the novel nature of the testing apparatus it was expected that subjects would improve substantially between the first and second testing sessions. Participants attended the testing venue 30 minutes early for their initial session to allow for introductions and pre-test familiarisation with the equipment. On this first occasion each subject was weighed and guided through the seven test battery before beginning the experiment proper. In addition, each subject repeated their initial session at the end of the test regime. Data from the initial familiarisation and first sessions have been treated as rehearsal and excluded from the results. Individual schedules were balanced across experimental conditions as far as practicable. As is often the case in within-groups repeated measures regimes (Bennett & Samson, 1991;Shapiro & Nathan, 1986; Sdao-Jarvie & Vogel-Sprott, 1992; Beirness & Vogel-Sprott, 1984) a degree of flexibility in between test interval was necessitated by subject availability constraints. Mean inter-test interval was 6.68 days with a one day minimum.

Specified reporting time was 30 minutes prior to the scheduled testing time (i.e. subjects arrived at 0830 for 0900 hour sessions). Beverages were administered and twenty minutes were allocated for food and beverage consumption, followed by a ten minute waiting period to allow the alcohol to take effect.

Subjects then proceeded to the testing area adjacent. Once seated conformably at the simulation apparatus drivers where asked firstly if the cursor arrow was visible on their visual display unit and secondly if it moved in response to a turn of the steering wheel. Tests were presented in the same sequence at each individual session with subjects advised as to the nature and duration of each task prior to its commencement.

Subjects were given no feedback as to their absolute or relative performance scores throughout the study. Firstly, because reinforcement is reported to reduce alcohol induced impairment of psychomotor performance (Haubenreisser and Vogel-Sprott, 1987; Brown et al, 1980; Vogel-Sprott and Sdao-Jarvie 1989; Beirness and Vogel-Sprott, 1984) and, secondly, to avoid progressive performance increment as a function of intra- or inter-subject competition. The word "test" was not used in description of any of the tracking tasks, again to avoid invoking competition.

At the end of each individual session the subject was thanked for his participation and the timing of his next session confirmed. Subjects were instructed not to drive or engage in any hazardous activities for four hours post alcohol-consumption, New Zealand Army policy extended the driving veto to six hours.

3.9. Statistical Analyses

In his dissertation on chronobiological research methods, Monk (1982) cites analysis of variance as the mode of analysis most typically used in pursuit of time of day effects and interaction effects. Monk (1982), however, cautions that this type of analysis is "conservative" with respect to time of day variations and this insensitivity increases with the number of time conditions. Within groups repeated measures designs increases statistical power as does inflating sample size; ironically these two features tend to be antagonistic in practice, in that the level of commitment required from individual subjects involved in repeated measures time series research tends to limit sample size. Recruitment and testing of the sixteen subjects in this study took 18 months and was only possible due to an extraordinary level of commitment by the personnel of the New Zealand Army's Burnham Military Camp.

While a number of cosinor modes of analysis are described in the literature, the integrity of what are essentially time series measures when applied to only four time conditions are debatable. Earlier cosinor methods such as Fourier Analysis and Minnesota Cosinor Technique (Monk, 1982) require either a few subjects sampled at many points across a long time series or a large subject group for a short duration. In either case Orr and Naitoh (1975) are sceptical of the power of time series of less than 200 points and cite 80 as an absolute minimum. The current study has a baseline time series of 64 points rendering use of either Fourier or Minnesota Cosinor Analyses at best inadvisable. Later versions of cosinor analyses (Monk & Fort, 1983) are described in the literature and while these are more sophisticated the number of time points in the series remains an issue.

Repeated measures analysis of variance were conducted independently for each of the seven tests included in the battery. Raw mean error and lag scores were each analysed as follows:

1. All 4 time conditions independent of alcohol (1 x 4 analysis of variance)

2. All 4 time conditions for alcohol and nil alcohol conditions (2 x 4 ANOVA)

3. 1300 and 1800 hour conditions for alcohol and nil alcohol after Horne et at 1991 (2 x 2 ANOVA).

4. 0900 and 0100 hour conditions for alcohol and nil alcohol (2 x 2 ANOVA). Contrasting a body temperature phase high at a time of day not traditionally associated with alcohol consumption with an early morning temperature trough at approximately public house closing time.

In addition the effect size index "f" (Cohen, 1988) was calculated across the four times of day to determine the extent to which daily mean error and lag scores differ under alcohol relative to nil alcohol conditions for each of the seven tests. An estimate of the proportion of population variance attributable to the presence of alcohol "n" was extracted from the effect size index "f" on each test measure (Cohen, 1988).

4. RESULTS

4.1. Horne and Ostberg "Morningness-Eveningness" Scale (1976)

The subject group proved homogenous in their lack of morning or eveningness. One individual recorded a slight morning preference (69), the balance fell within the "neither type range" (42-58). The group average score was 55.1 ± 5.1 (neither type).

4.2. The Rotter "Internal-External" Locus of Control Scale (1966)

Scores on the Rotter "Internal-External" Locus of Control Scale (1966) are expressed in the "external". The higher the score the more weight afforded external agents in determination of life events. Locus of control measures were normally distributed across the medium range with no extremes of opinion at either pole. The group mean was 11.27 ± 1.98.

4.3. Performance Means

Measures of mean error (the average horizontal distance between the arrow point and target) and lag (average delay between response and target in ms) were calculated for all seven tracking tasks, in addition to reaction times for steps out and back on the Step Non-preview tracking task. Group mean alcohol and alcohol free performance on each of the seven tracking tasks are shown in Table 1. Overall tracking accuracy as indicated by mean error scores was poorer under alcohol relative to nil alcohol performance. The size of the mean lag score under both alcohol and nil alcohol conditions varied according to the predicability of the task. The tasks which incorporated a visual preview of the course to be tracked returned lower lag scores than non-previewed tasks.

Table 1. Group Mean Error, Mean Lag and Mean Reaction Time scores under alcohol and nil alcohol performance across four times of day.

Mean Error	**0900 hours**		**1300 hours**		**1800 hours**		**0100 hours**	
	Nil A.	**Al.**	**Nil A.**	**Al.**	**Nil A.**	**Al.**	**Nil A.**	**Al.**
Sine Non-prev.	2 93 ±0.91	3.42 ±1.07	3.08 ±0.91	3.13 ±0.81	3.23 ±0.82	3.23 ±0.82	3.06 ±0 90	3 55 ±1 18
Sine Preview	2.88 ±1 00	2.96 ±0.59	2.84 ±0.72	3.17 ±0.64	2.88 ±1.10	3.43 ±0.84	2.77 ±0 66	3 53 ±1.10
Random Non-p.	3.40 ±0 86	3.97 ±1.10	3.50 ±0.87	3.89 ±1.10	3.55 ±0.90	4.05 ±0.90	3.53 ±1 00	4 23 ±1 30
Random Prev.	2.39 ±0.48	2.68 ±0.51	2.39 ±0.64	2.58 ±0.53	2.45 ±0 54	2.80 ±0.52	2.49 ±0.39	2 85 ±0 62
Step Non-prev.	7.08 ±1.20	7.71 ±1.20	7.23 ±1.10	7.77 ±1.10	7.14 ±0.90	7.74 ±1.10	7 57 ±1.10	7 81 ±1 10
Step Preview	2.82 ±0.94	2.99 ±0.87	2.90 ±0.96	2 98 ±1.00	2.95 ±1.00	3 21 ±0.91	2.97 ±1.00	3 14 ±1 00
Combination T.	8.33 ±0 96	8.89 ±1.00	8.54 ±0 96	9.05 ±1.10	8.54 ±0 93	9.48 ±1.20	8.66 ±1.30	9.19 ±1 10.
Mean Lag	**0900 hours**		**1300 hours**		**1800 hours**		**0100 hours**	
	Nil A.	**Al.**	**Nil A.**	**Al.**	**Nil A.**	**Al.**	**Nil A.**	**Al.**
Sine Non-prev.	40.9 ± 24	40.7 ± 31	36.8 ± 24	26.2 ± 21	41.2 ± 28	36.1 ± 23	39.9 ± 24	42.3 ± 28
Sine Preview	14.0 ± 46	5.8 ± 36	10 4 ± 42	10.4 ± 45	6.9 ± 49	8 8 ± 51	1.2 ± 41	10 4 ± 43
Random Non-p.	83.2 ± 30	92.9 ± 40	78.5 ± 39	91.1 ± 45	86.3 ± 31	92.2 ± 30	85.5 ± 33	100.8 ± 43
Random Prev.	50.1 ± 36	54.4 ± 44	51.7 ± 34	56.0 ± 34	51.2 ± 39	54 6 ± 41	46.7 ± 38	56 7 ± 44
Step Non-prev.	566 2 ±115	605.8 ±124	575.2 ±102	614 3 ±110	559.5 ± 91	606.6 ± 96	607.7 ±103	618 0 ±102
Step Preview	175.2 ±117	177.7 ±105	182.6 ±115	175.6 ±121	185.9 ±123	188 8 ±122	192.7 ±119	187 7 ±131
Combination T.	442.2 ± .50	458.2 ± 56	440 8 ± 44	477.2 ± 52	441.4 ± 42	460.5 ± 59	451.6 ± 51	459.0 ±105
Reaction Time	**0900 hours**		**1300 hours**		**1800 hours**		**0100 hours**	
Step Non-preview	**Nil A.**	**Al.**	**Nil A.**	**Al.**	**Nil A.**	**Al.**	**Nil A.**	**Al.**
Step Out	392.7 ± 69	430.7 ± 83	399.7 ± 57	434.2 ± 60	387.6 ± 61	435.4 ± 64	415.9 ± 58	447 3 ± 71
Step Back	372.9 ± 60	403.6 ± 75	368.1 ± 53	415.9 ± 62	367.6 ± 56	398.5 ± 57	384.5 ± 58	411.8 ± 63

"Nil A" indicates alcohol free, "Al" alcohol effected performance.

Group means on alcohol relative to nil alcohol performance on measures of mean error, lag and reaction time are illustrated graphically in Appendix 5. (Figures 4 to 19).

Standard deviation on each of the three measures (mean error, lag and reaction time) were proportionally much higher on low error, than high error tasks. As illustrated in Table 2. the standard deviations when expressed as a proportion of group mean score were similar under alcohol versus nil alcohol performance on the same task, but varied dramatically from task to task. Within group variability is most pronounced in respect of the predictable Sine Preview task, on which the standard deviations under alcohol (43.7) and nil alcohol (44.5) performance on lag measures equate to 491.6% and 549.4% respectively, when expressed as a proportion of alcohol/nil alcohol group mean lag scores. Also shown in Table 2. is the percentage increase in errors made during alcohol relative to nil alcohol performance on each of the three measures (mean error, lag and reaction time). The large percentage differences (alcohol vs alcohol free performance) on measures of mean error on the Sine Non-preview, Sine Preview, Random and Random Preview tasks do not parallel the size effect indices (Table 3.) calculated in respect of these same tasks. High within group variability is likely to account for the lack of consistency between the percentage error increase in alcohol relative to nil alcohol performance (Table 2.) and alcohol effect size indices (Table 3.). Similar caution is necessary in interpretation of the percentage alcohol free/alcohol performance difference on lag scores.

le 2. Daily (all time conditions) Group Mean Error, Mean Lag and Mean Reaction Time scores under alcohol and nil alcohol performance. Including the size of the SD (as a percentage of the mean score), and percentage difference in alcohol free and alcohol effected scores.

Mean Error	**Nil Alc.**	**Size of SD (%)**	**Alcohol**	**Size of SD (%)**	**Nil Alcohol/Alcohol % Difference**
Sine Non-preview	3.07±0.88	28.8%	3.33±0.97	29.1%	8.47%
Sine Preview	2.85±0.87	30.5%	3.27±0.79	24.2%	14.74%
Random Non-preview	3.49±0.91	26.0%	4.04±1.10	27.2%	15.76%
Random Preview	2.42±0.51	21.2%	2.73±0.54	20.0%	12.81%
Step Non-preview	7.25±1.10	14.8%	7.76±1.10	14.5%	7.03%
Step Preview	2.91±0.97	33.5%	3.08±0.94	30.7%	5.84%
Combination Tracking	8.52±1.04	12.2%	9.15±1.10	12.0%	7.39%
Mean Lag	**Nil Alc.**	**Size of SD (%)**	**Alcohol**	**Size of SD (%)**	**Nil Alcohol/Alcohol % Difference**
Sine Non-preview	39.7± 25.0	63.0%	37.1± 25.7	69.4%	-6.55%
Sine Preview	8.1± 44.5	549.4%	8.9± 43.7	491.6%	9.88%
Random Non-preview	85.0± 33.2	39.1%	94.2± 39.5	41.9%	10.82%
Random Preview	49.9± 36.7	73.6%	55.4± 40.7	73.5%	11.02%
Step Non-preview	577.2±102.7	17.8%	611.2±108.0	17.7%	5.89%
Step Preview	184.1±118.5	64.4%	182.5±119.7	65.6%	-0.87%
Combination Tracking	440.0± 46.7	10.5%	463.7± 68.0	14.7%	4.44%
Reaction Time Step Non-preview	**Nil Alc.**	**Size of SD (%)**	**Alcohol**	**Size of SD (%)**	**Nil Alcohol/Alcohol % Difference**
Step Out	399.0± 61.2	15.3%	436.9± 69.5	15.9%	9.50%
Step Back	374.3± 56.7	15.2%	407.4± 64.2	15.8%	8.84%

4.4. Size Effect Index

Effect size indices "f" (Cohen, 1988) shown in Table 3. were calculated across the four times of day to determine the extent to which daily mean error and lag scores differ under alcohol relative to nil alcohol conditions for each of the seven tests. An estimate of the proportion of population variance attributable to the presence of alcohol "n" was extracted from the effect size index "f." on each test measure (Cohen, 1988). For mean error measure large alcohol effect indices (f>.40) were found for five tracking tasks: Step (f=1.19), Random (f=1.14), Combination (f=0.76), Random Preview (f=0.51) and Sine Preview. Step Preview and Sine Tracking returned medium effect sizes.

As shown in Table 3., tracking accuracy as indicated by measures of mean error consistently returned higher alcohol effect sizes than lag (ms delay between target and response) on each of the seven tasks. Non-preview Step (f=0.97), Random (f=0.55), and Combination (f=0.41) Tracking tasks return large alcohol effect size indices on lag measures. Small alcohol effect sizes were found for Non-preview Sine Tracking and the three Preview Tracking tasks: Sine Preview, Random Preview and Step Preview. Reaction Times on Step Tracking task were seriously effected on both the outward (f=3.16) and return steps (f=2.4).

Table 3. Effect Size Index (f.) the degree of difference between alcohol and nil alcohol conditions across 4 times of day and the proportion of population variance attributable to alcohol (n.).

	Mean Error		Mean Lag		Reaction Time Step Out		Reaction Time Step Back	
	f.	**n.**	**f.**	**n.**	**f.**	**n.**	**f.**	**n.**
Sine Non-prev.	.33	.11	-.16	NA				
Sine Preview	.44	.16	.02	.00				
Random Non-p.	1.14	.56	.55	.23				
Random Prev.	.51	.20	.19	.03				
Step Non-prev.	1.19	.60	.97	.48	3.16	.83	2.40	.72
Step Preview	.38	.12	.03	NA				
Combination T.	.76	.37	.41	.14				

4.5. Analyses of Variance

4.5.1. Alcohol and nil alcohol performance at 0900, 1300, 1800 and 0100 hours (2 x 4 ANOVA)

Analysis of mean error scores on alcohol relative to no alcohol performance across all four time conditions returned a significant main alcohol effect on all tasks (Table 2.). Step tracking alone of the seven tasks approached significance on time of day effect (F=2.69: p=.058).

No significant alcohol x time of day interaction was found on measures of mean error; the only incidence that approached significance ($F=2.26$: $p<0.10$) on non-previewed Sine Tracking. Group averaged mean error scores on Sine Tracking under alcohol relative to nil alcohol conditions across the four time conditions are illustrated in Figure 1.

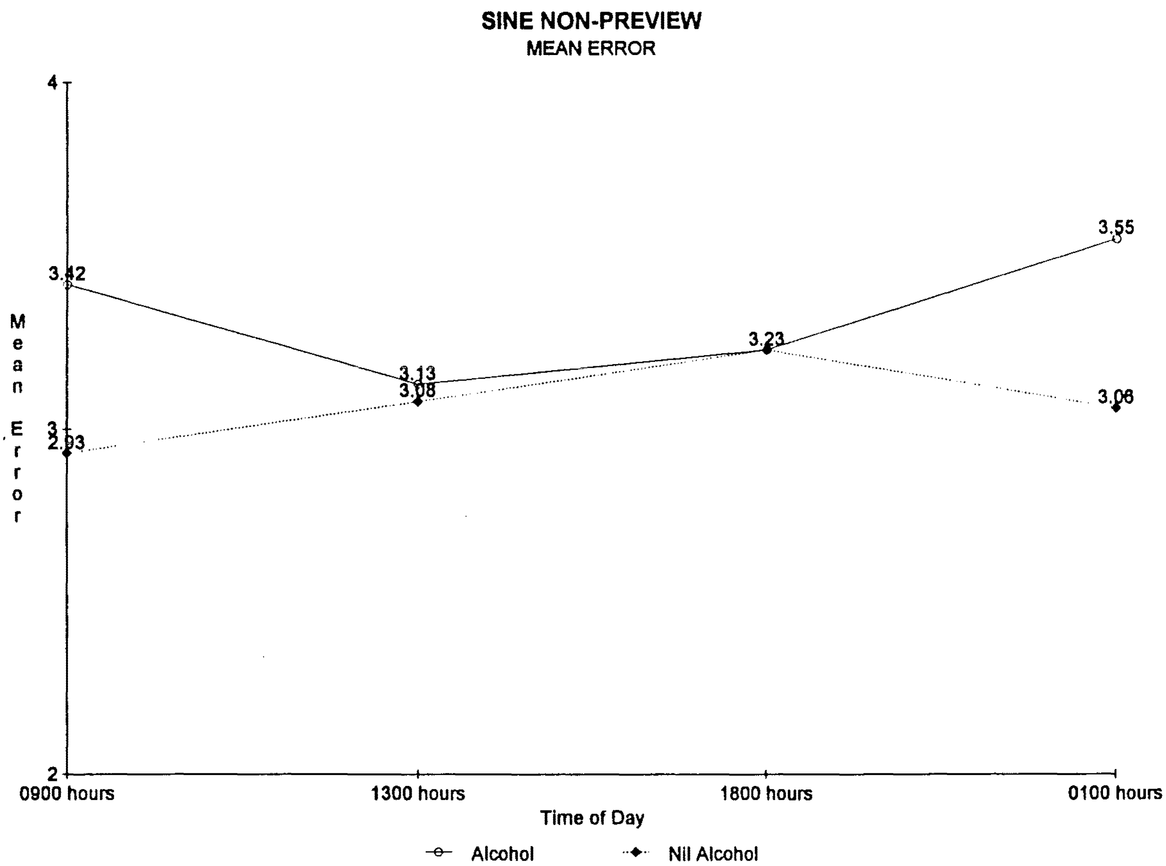

Figure 1: Group Averaged mean error scores on alcohol and alcohol free performance on Non-preview Sine Tracking at 0900, 1300, 1800 and 0100 hours.

Significant alcohol effects were found on lag for Random, Step and Combination Tracking. On tasks incorporating a visible pre-plotted course (Sine Preview, Random Preview and Step Preview) the effect of alcohol on lag scores was not significant. In the absence of visual course preview, regularity and predicability of motion emerged as a factor in the extent to which alcohol effects performance. No significant alcohol effect was found on lag measures for the regular and predictable non-previewed Sine Tracking task. Step Tracking alone returned a significant time of day effect (F=4.25: p=0.01) on mean lag. Group averaged mean lag scores on Non-preview Step Tracking under alcohol relative to nil alcohol conditions across the four time conditions are illustrated in Figure 2.

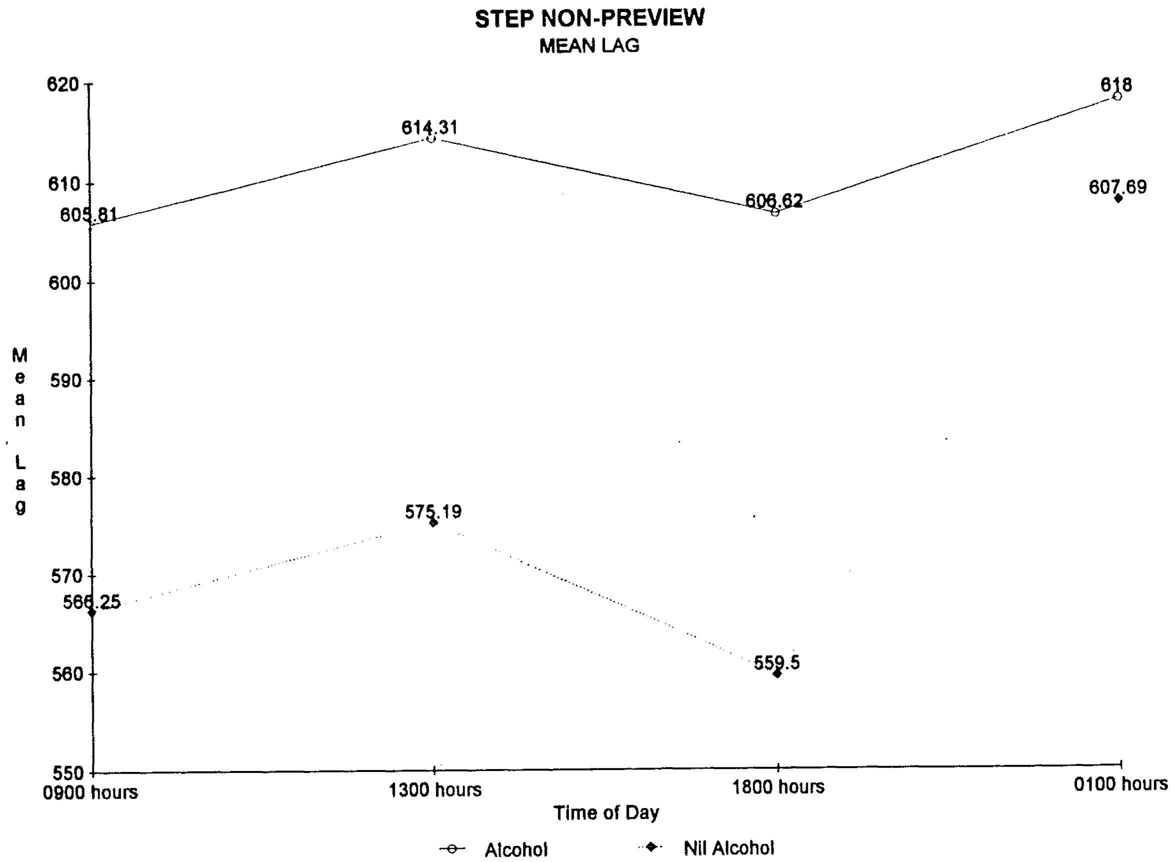

Figure 2: Group Averaged mean lag scores on alcohol and alcohol free performance on Non-preview Step Tracking at 0900, 1300, 1800 and 0100 hours.

Reaction time on the steps out ($F=41.61$: $p<0.01$) and back ($F=38.28$: $p<0.01$) from centre on the non-reviewed Step Tracking task were significantly effected by alcohol. No time of day effects were found on measures of reaction time.

No significant time of day/alcohol interaction was recorded on any of the measures (mean error, mean lag or reaction time) subject to 2 x 4 analysis of variance.

Table 3. Summary of ANOVA's for alcohol and nil alcohol performance at 0900, 1300, 1800 and 0100 hours. (2 x 4 ANOVA)

	df = 1:15 Alcohol		df = 3:45 Time of Day		df = 3:45 Alcohol x Time	
Mean Error	**F.**	**p.**	**F.**	**p.**	**F.**	**p.**
Sine Non-preview	4.95	.042*	.64	.593	2.26	.095~
Sine Preview	11.64	.004**	1.23	.311	1.09	.362
Random Non-prev.	39.03	.000**	.87	.464	.71	.550
Random Preview	15.36	.001**	1.23	.308	.26	.850
Step Non-preview	51.88	.000**	2.69	.058~	.94	.429
Step Preview	4.69	.047*	1.48	.233	.38	.765
Combination Tracking	26.51	.000**	1.53	.219	.96	.419
Mean Lag						
Sine Non-preview	1.02	.329	1.95	.135	.71	.553
Sine Preview	.02	.888	.16	.925	.58	.643
Random Non-prev.	9.77	.007**	.97	.414	.52	.671
Random Preview	1.38	.258	.06	.980	.12	.950
Step Non-preview	30.96	.000**	4.25	.010**	.84	.478
Step Preview	.03	.855	.80	.500	.15	.929
Combination Tracking	6.21	.025*	.24	.867	.94	.430
Reaction Time (Step Non-preview)						
Step out	68.84	.000**	3.38	.026*	.60	.621
Step back	54.30	.000**	2.26	.094	.83	.483

** = significant $p<0.01$, * = significant $p<0.05$, ~ = approaching significance $p=<0.1$

4.5.2. 1300 and 1800 hours only Alcohol/Nil Alcohol x 2 times of day

Performance measures from 1300 and 1800 hour time conditions were subject to independent 2 x 2 ANOVA after Horne and Baumber (1991) and Horne and Gibbons (1991). Results of this analysis are shown in table 4.

Six of the seven tasks demonstrated a significant main alcohol effect on measures of mean error at 1300 and 1800 hours. In contrast to finding from 2 x 4 ANOVA described in Table 2., in which a significant main alcohol effect was found for mean error on the non-previewed Sine Tracking task no such effect was evident in comparison of 1300 and 1800 hours conditions.

Mean lag on was significantly affected by alcohol on the Combination Tracking and Step Tracking tasks. Random Tracking which had been significantly affected by alcohol on lag measures when analysed across all four time conditions (Table 2.) did not return a significant alcohol effect on 2 x 2 ANOVA at 1300 and 1800 hours.

In contrast to the findings of Horne et al. (1991) no significant time of day effect nor alcohol x time of day interaction was recorded for mean error, lag or reaction time measures following analysis of performance at 1300 and 1800 hours.

Table 4. Summary of ANOVA's for alcohol and nil alcohol performance at 1300 and 1800 hours. (2 x 2 ANOVA)

	df = 1:15		df = 3:45		df = 3:45	
	Alcohol		**Time of Day**		**Alcohol x Time**	
Mean Error	**F.**	**p.**	**F.**	**p.**	**F.**	**p.**
Sine Non-preview	.04	.851	.73	.406	.04	.839
Sine Preview	6.13	.026*	.89	.361	.41	.534
Random Non-preview	12.58	.003**	.49	.493	.31	.585
Random Preview	8.08	.012*	1.41	.253	.91	.356
Step Non-preview	29.65	.000**	.37	.551	.08	.780
Step Preview	6.88	.019*	2.41	.141	1.13	.304
Combination Tracking	17.81	.001**	1.55	.225	2.27	.152
Mean Lag						
Sine Non-preview	2.39	.143	2.94	.730	.12	.730
Sine Preview	.02	.892	.32	.582	.03	.870
Random Non-preview	4.04	.063~	.76	.397	.49	.496
Random Preview	.52	.481	.02	.894	.01	.920
Step Non-preview	17.14	.001**	2.64	.124	.18	.677
Step Preview	.07	.801	.74	.402	.33	.571
Combination Tracking	11.43	.004**	.58	.458	1.04	.323
Reaction Time (Step Non-preview)						
Step Out	41.61	.000**	.61	.447	1.37	.260
Step Back	38.28	.000**	2.75	.118	1.18	.290

** = significant p<0.01, * = significant p<0.05, ~ = approaching significance p=<0.1

4.5.3. Comparison of Alcohol/Nil Alcohol Performance at 0900 and 0100 hours

Separate 2 x 2 ANOVA was calculated comparing alcohol and nil alcohol performance at 0900 and 0100 hour conditions. Results of this analysis appear in Table 5.

Five (Sine, Random, Random Preview, Step and Combination) of the seven tracking tasks returned significant main alcohol effects at 0900 and 0100 hours on mean error measures. Sine tracking returned a significant main alcohol effect on 0900 vs 0100 hour but not under 1300 and 1800 hour comparison, yet returned no significant time of day nor interaction effects under either 2 x 2 ANOVA analysis. No significant alcohol effect was found on mean error measure for Sine Preview, yet the both the time of day ($F=3.24$: $p<0.1$) and interaction effects ($F=3.39$: $p<0.1$)approached significance on this task. Group averaged mean error scores on Sine Preview under alcohol relative to nil alcohol conditions across the four time conditions are illustrated in Figure 3.

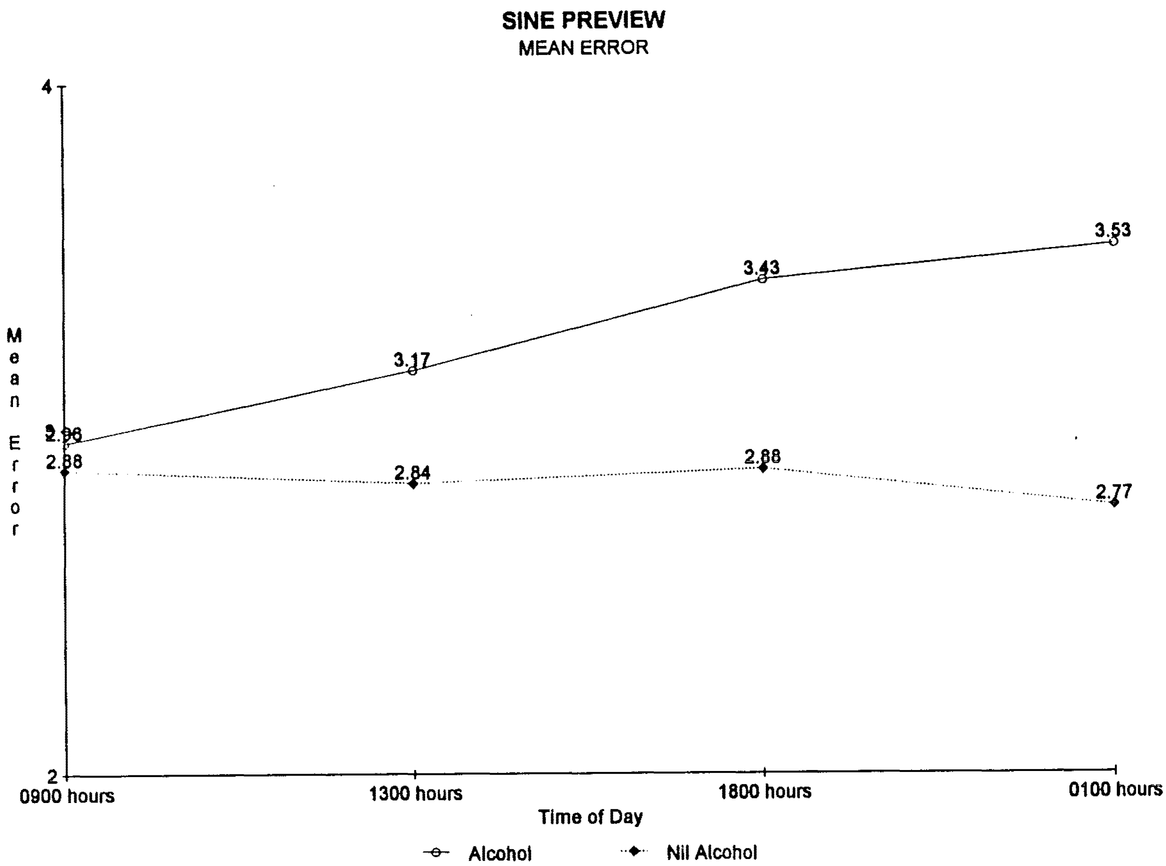

Figure 3: Group Averaged mean error scores on alcohol and alcohol free performance on Sine Preview at 0900, 1300, 1800 and 0100 hours.

A significant (F=4.88: p=.04) time of day effect was found for Step Tracking on mean lag measure at 0900/0100 hour analysis in contrast to1300 vs 1800 hours comparison which returned no such effect. See Table 2. for a graphic representation of averaged group mean lag scores under alcohol and alcohol free performance across the four time conditions.

Table 5. Summary of ANOVA's for alcohol and nil alcohol performance at 0900 and 0100 hours. (2 x 2 ANOVA)

	df = 1:15		df = 3:45		df = 3:45	
	Alcohol		Time of Day		Alcohol x Time	
Mean Error	F.	p.	F.	p.	F.	p.
Sine Non-preview	8.96	.009**	.62	.442	.00	.974
Sine Preview	3.28	.090~	3.24	.092~	3.39	.086~
Random Non-prev.	29.19	.000**	2.46	.137	.41	.530
Random Preview	5.22	.037*	1.53	.235	.11	.746
Step Non-preview	14.38	.002**	4.88	.043*	1.47	.245
Step Preview	2.33	.147	2.36	.145	.00	1.000
Combination Tracking	8.67	.010**	2.18	.160	.02	.892
Mean Lag						
Sine Non-preview	.08	.778	.00	.949	.14	.711
Sine Preview	.00	.952	.22	.649	2.03	.175
Random Non-prev.	9.69	.007**	1.18	.294	.73	.408
Random Preview	1.08	.316	.01	.928	.18	.675
Step Non-preview	6.33	.024*	5.68	.031*	.86	.369
Step Preview	.01	.930	1.51	.238	.15	.700
Combination	1.08	.314	.13	.719	.18	.675
Reaction Time (Step Non-preview only)						
Step Out	34.28	.000**	6.91	.019*	.18	.677
Step Back	30.14	.000**	1.89	.189	.04	.840

** = significant p<0.01, * = significant p<0.05, ~ = approaching significance p=<0.1

Lag scores on both Random and Step tracking were significantly effected by alcohol across 0900 and 0100 hours, as were both measures of reaction time on the latter task. In addition to main alcohol, the Step tracking task returned significant time of day effect on the outward step reaction time measure.

No alcohol time of day interaction was recorded on any of these measures.

4.5.4. Nil Alcohol Performance x 4 times of day

Finally all ANOVA was calculated for nil alcohol performance across all four time conditions (Table 6.). Step tracking alone returned significant time of day effects under nil alcohol conditions on mean error, lag, and outward step reaction time.

Table 6. Contrast of nil alcohol mean error, lag and reaction time (Step Tracking only) scores at 0900, 1300, 1800 and 0100 hours. (1 x 4 ANOVA).

	Mean Error		Mean Lag		Reaction Time Step Out		Reaction Time Step Back	
	F.	p.	F.	p.	F.	p.	F.	p.
Sine Non-preview	.78	.509	.28	.838				
Sine Preview	.08	.973	.77	.516				
Random Non-prev.	.38	.768	.71	.553				
Random Preview	.31	.820	.18	.911				
Step Non-prev.	3.32	.028*	3.66	.019*	3.72	.017*	2.16	.106
Step Preview	.64	.594	.57	.635				
Combination T.	.66	.579	.59	.626				

** = significant p<0.01, * = significant p<0.05, ˜ = approaching significance p=<0.1

4.6. Summary

No significant alcohol x time of day interaction was recorded for mean error, lag or reaction time measure on any of the seven tracking tasks under analysis of alcohol relative to nil alcohol performance across the four times of day.

Overall tracking accuracy as indicated by mean error measures was significantly effected by alcohol. The impact of alcohol on lag varies with the level of task unpredictability, with non-preview tracking tasks more susceptible to the performance inhibiting effects of alcohol. The unpredictable Step Tracking task consistently returned significant main alcohol effects on measure of mean error, lag and reaction time.

Step tracking was the only task to return a time of day effect under nil alcohol conditions, this it did on mean error, lag and step out reaction speed measures.

5. DISCUSSION

5.1. Synopsis of Findings

Overall error scores on most tasks demonstrated statistically significant main alcohol effects. The size index (f) of the alcohol effect (Cohen, 1988) typically increased with level of difficulty or unpredictability of the task. The impact of alcohol on lag scores reflected the extent to which the task required a speedy response to an unpredictable target movement. Non-preview tracking tasks (with the exception of the more rhythmic Sine tracking task) demonstrated an increased susceptibility to the performance inhibiting effects of alcohol. Prior knowledge of the course on previewed tasks enabled the progress of the target to be anticipated, with this reduced need for quick response reflected in reduced lag errors. The very low or negative effect size indices for mean lag measures on Sine Preview, Sine Tracking and Step Preview tasks are a function of the increased tendency of some subjects to precede the target under alcohol relative to alcohol free performance. This increase in negative lag creates a false impression that lag errors are reduced under alcohol relative to nil alcohol performance. The Step Tracking task which has a high reaction speed component consistently returned significant main alcohol effects on measures of mean error, lag and reaction time.

No significant alcohol x time of day interaction was recorded for mean error, lag or reaction time measure on any of the seven tracking tasks under analysis of alcohol relative to nil alcohol performance across the four times of day. The only incidence which approached significance on alcohol x time interaction was returned under comparison of mean error and lag in Sine Preview performance at 0900 and 0100 hours. This was in contrast to Horne et al (1991) who report a significant alcohol/time of day interaction in respect of performance on monotonous simulated driving task at 1300 and 1800 hours. The post-lunch dip and early evening conditions were selected by Horne et al (1991) to demonstrate alcohol exacerbation of normal daytime sleepiness. These same time conditions were included in the present study firstly, to ascertain whether an alcohol time of day interaction effect was evident at these times in respect of performance on a battery of brief sensorimotor tasks, and secondly, as a reference point against which performance at 0900 and 0100 hours could be contrasted.

Horne et al (1991) focused on an aspect of alcohol effected driving relevant to the British situation. Using female subjects and a quantity of alcohol below the United Kingdom legal limit, these authors simulated a British "pub lunch" scenario and subsequent monotonous motorway driving task. The goal of the present study was to investigate diurnal variation in the extent to which alcohol effects driving related performance under New Zealand conditions. Male subjects were chosen due to the over-representation of 20-30 year old male drivers in the New Zealand road accident and drink-drive statistics, a dose of 2.26 ml/kg (37% alcohol) administered to produce a BAC approximating the legal maximum for driving on New Zealand roads, and a testing session (0100 hours) scheduled to coincide with public house closing time. The computerised driving assessment programme was adopted due to the relevance of tracking accuracy, lag and reaction speed to the real-life driving situation

5.2. The Effects of Alcohol on Psychomotor Performance and Implications for the Drinking Driver

The effects of alcohol on performance found in the present study are consistent with those reported by Moskowitz et al (1985), in that performance decrement increased with the level of task difficulty, but contrary to Kearney et al (1986) who describe simple one-dimensional tracking tasks as resistant to the deleterious effects of moderate doses of alcohol. Accuracy on the more difficult tasks was seriously effected (as quantified by effect size index) by alcohol at 2.26 ml/kg (37% alcohol), however alcohol induced performance deficit on the less challenging tracking tasks, although reduced, was also significant. While caution is necessary in generalising findings from the artificial off-road, to the real-life driving situation, new findings from the present study regarding the impact of alcohol on driving related sensorimotor performance (tracking accuracy, lag and reaction speed) have implications for road safety. Firstly, alcohol sufficient to produce BAC's approximating the legal limit for driving under New Zealand law (Ferrimond, 1990) has a significant negative impact on tracking accuracy across all levels of task difficulty. Secondly, the extent of the alcohol effect as indicated by size index (Cohen, 1988) was associated with the level of task unpredictability, with performance decrement reduced when a visual preview of the tracking course was available. These findings raise issues about the respective roles of visibility and road knowledge in the real-life drink driving context. Alcohol, night driving and an unfamiliar road is likely to be a particularly dangerous combination. Finally, the substantial impact of alcohol on reaction speed augurs badly for the alcohol affected driver confronted with an unexpected hazard.

5.3. Time of Day Effects, Nature and Duration of the Task

Early chronobiological research (Kleitman, 1963; Colquhoun, 1971) noted a parallelism between body temperature and measures of subjective arousal or "non-sleepiness". Both typically begin their ascent around the beginning of the activity cycle, increase throughout the morning, dip slightly post-lunch (Anderson et al, 1991, Colquhoun, 1982), ascend in the evening before plunging to an overnight trough after midnight. The arousal hypothesis (Kleitman, 1963; Colquhoun, 1971) construed diurnal performance fluctuations in terms of alertness and argued that performance was more or less susceptible to diurnal variation according to the degree of arousal elicited by the particular task or working environment. The parsimonious arousal hypothesis lost favour as a growing body of chronobiological literature reported apparently divergent rhythms for different tasks (Webb, 1982). In respect of substance interaction with diurnal performance fluctuations, arousal is indicated as one of several potential mediating factors.

Both the nature and duration of the task have been cited as variables in the extent to which performance is influenced by diurnal variation. A task length threshold in performance susceptibility to post-lunch effects is suggested by Smith and Miles (1986) and supported Rogers et al (1989) who have reported early morning performance speed and accuracy deficits across a range of moderate to long (10 to 26 minutes) tasks incorporating sustained attention, tracking, reaction speed, visual, auditory and complex vigilance. The tasks which returned significant alcohol/time of day interactions in the Horne and Gibbons (1991) and Horne and Baumber studies were a monotonous 60 minute auditory vigilance task in the former study, and a 20 minute simulated motorway driving task in the latter. While the cumulative duration of the seven test battery used in the present study was 12 minutes time on task, individual tests were brief (70-120 seconds) and of a level of difficulty sufficient to demand full concentration. Brief stimulating tasks of this type may be more likely to promote enhanced performance through increased motivation than exacerbate sleepiness through monotony. In contrast statistically reliable rhythms have been reported in a battery of brief (two to six minute) reaction speed tasks (Naitoh et al, 1985). Consistent with Naitoh et al (1985), but contrary to the arousal theory, the only one of the seven tasks which demonstrated a significant time of day effect under nil alcohol performance in the present study, was (Step Non-preview) a two minute challenging task with a high reaction speed component. Contrary to those studies which have linked arousal, psychomotor performance and body temperature cycles, Payne (1989) describes a 0900 hour performance peak on three x one minute mirror tracking tasks, with tracking accuracy declining across the morning, making a dramatic recovery at 1400 before falling progressively to a 1700 hour low. The present study provided little evidence in support of circadian rhythmicity in brief sensorimotor tasks. Performance on the one (Step Non-preview) task, which returned a significant time of day effect under alcohol free performance, contrary to the rhythm pattern described by Payne (1989), was poorest at 0100 hours on measures of tracking accuracy, lag and reaction time in response to the outward step.

5.4. Alcohol x Time of Day Interaction

Alertness may be stimulated or inhibited under alcohol depending on the quantity administered. The combined effects of fatigue and alcohol have found to be antagonistic, rather than additive, on a visual task at high alcohol doses (Smith, Sinha & Williams, 1989-90). The apparent isolation of alcohol x time of day interaction on brief cognitive and eye-hand skill tests by Reinberg (1992) may be explicable in terms of an alcohol x fatigue interaction. Reinberg (1992) found self-rated inebriety to peak at 2300 hours and coincide with worst performance on speed number addition and eye-hand co-ordination tests. The extent of the difference between baseline and alcohol effected performance on numbers addition increased progressively from the onset of drinking with the task performance at 0700, 1100 and 2300 hours worst at 90 minutes.

Subjects in the Reinberg study fasted for 12 hours before, and received no food during or after alcohol ingestion. Horne and Gibbons' (1991) pilot study indicates that alcohol administered under these circumstances would be well in decline by 90 minutes post ingestion. It seems possible that the poor performance of subjects in the Reinberg study at 90 minutes after alcohol at 2300 hours (30 minutes after the subjects habituated bed time) may be fatigue related. Descending blood alcohol concentrations may have dropped to a level insufficient to inhibit fatigue. Smith et al (1989-90) report that the performance inhibiting effects of fatigue and alcohol *are* additive at lower blood alcohol concentrations.

The alcohol dose used in the present study was (2.26 ml/kg, 37% alcohol) sufficient to produce a blood alcohol level approximating the legal limit for driving an automobile on New Zealand roads. This dose falls midway between the moderate (1.06 g/kg 95% by volume ethanol) and low (0.70 g/kg 95% by volume ethanol) doses defined by Smith et al (1989-90), and may have been sufficient to produce a fatigue antagonistic response. Because testing in the current study was deliberately scheduled to precede the descending limb of the blood alcohol curve no information is available regarding performance on the sensorimotor test battery at reduced blood alcohol concentrations. The Horne et al (1991) studies returned significant alcohol x time of day interactions on sustained performance with moderate (1.72 ml/kg) and low (0.86 ml/kg) doses of alcohol administered to female subjects.

A major difference in procedure between the present study, and those which have reported significant alcohol x time of day interactions using male subjects and brief tasks (Jones, 1974; Reinberg, 1992), is the interval between alcohol consumption and task performance. Task performance on the present study began 30 minutes from beginning alcohol consumption, after the recommendations of Horne et al (1991). Whereas Jones (1974) and Reinberg (1992) delayed performance testing to 121-147 minutes and 90 minutes respectively. Time lapse between alcohol consumption and task performance was investigated by Reinberg (1992), who reported a significant alcohol x time of day interaction at ingestion at 2300 hours only when task performance was delayed 90 minutes post-consumption. This interaction effect is unlikely to be purely performance time related in that the testing schedule of the present study included a session at 0100 hours, half an hour later than subjects were required to perform in the Reinberg study (1992). Furthermore the decrement in performance capacity to 90 minutes post-consumption does not appear to be progressive; subjects in the present study began tracking at 30 minutes, and completed the last task in the battery at around 45 minutes, after the onset of drinking. If the performance decline from consumption onset to 90 minutes post-ingestion were linear, the last task in the testing battery (Combination Tracking) would have been most likely to return an interaction effect. This was not the case. The tasks on which mean error measures did approach significance on alcohol x time of day were Preview and Non-preview Sine Tracking, placed second and first respectively, in the testing sequence.

While quantity appears to mediate the extent and direction of alcohol's influence on arousal, diurnal or otherwise, dose alone is insufficient to explain the absence of diurnal performance fluctuations and alcohol x time of day interaction effects in the present study. Only one, Step Non-preview, of the seven tracking tasks demonstrated a susceptibility to diurnal variation under nil alcohol performance. Clearly alcohol dose is only one of a variety of factors capable of mediating the time of day/ performance relationship.

5.5. Individual Differences

5.5.1. Morning Evening Performance Preference

Harma and Ilmarinen et al (1988) suggest that tolerance for shift work may be more often associated with personality than physiological differences. Morning/evening preference has been found to be associated with the timing of both body temperature and performance peaks (Horne & Ostberg, 1977; Anderson et al, 1991). The subjects in the present study, with the exception of one moderate morning type, all returned scores in the "neither type" category on the Horne and Ostberg (1976) "Morningness-Eveningnness" Scale. Female subjects in the Horne et al studies (1991) were also identified as neither type on the same scale. Distinct differences in body temperature phase peak and preferred timing of work and rest schedules have been recorded for individuals classified as morning or evening types. It is unclear however whether the neither type classification on the Horne and Ostberg (1976) instrument reflects a mid-day, mid-night, or no particular time preference (Anderson, et al, 1991). While use of this instrument in both the Horne et al (1991), and the present and studies demonstrated homogeneity of sample in that no extreme morning or evening preference were identified it does not eliminate the possibility that a "neither type" classification may equate with increased tolerance for irregularly timed work schedules, or that being neither morning or evening type may by default indicated midday or midnight preference.

Military subjects may be a population with some immunity to diurnal performance fluctuations. The propensity for 24 hour performance is vital to military operations and in promoting a career removed from the "nine to five", the Armed Forces may attract those with increased tolerance for irregular work schedules. Several authors describe a "late peaking" phenomena in the performance rhythms of young military subject populations (Blake, 1972; Colquhoun et al, 1969; Adam et al, 1972).

5.5.2. Physical fitness

Physical fitness is reported by Atkinson, Coldwell and Reilly (1993) to correlate with higher body temperature amplitude, which in turn has been associated with increased tolerance to irregular work schedules. Circadian troughs in subjective arousal and left grip strength were significantly less pronounced in physically active subjects.

Subjects in the present study had regular exercise regimes and were subject to annual fitness test. In addition to recruitment bias in favour of shift work tolerance, military discipline, motivation and physical training regimes may further reduce susceptibility to diurnal performance variation. Certainly subjects in the present study were remarkably amiable about turning out after midnight and, with the exception of the Step Non-preview task, demonstrated no significant performance deficit at this late hour relative to the three other time conditions.

5.5.3. Motivation

Given that motivation was sufficient to mediate some aspects of performance at the moderate alcohol dose used in the present study, motivation may well be sufficient to overwhelm fragile time of day effects, under alcohol or nil alcohol conditions. Alcohol expectancy in a proportion of male social drinkers has been found to impact on performance in a direction antagonistic to alcohol, producing improved performance under placebo or low alcohol doses relative to nil alcohol baseline. (Newlin, 1985; Brown et al, 1980), Rosenow et al, 1981). A proportion of male drinkers apparently anticipate alcohol induced performance impairment and endeavour to compensate. Tangible and verbal reinforcement have also been reported to reduce alcohol induced impairment of psychomotor performance (Haubenreisser et al, 1987; Brown et al , 1980; Vogel-Sprott et al, 1989; Beirness et al, 1984). The alcohol dose was sufficient in the present study to produce a performance deficit beyond the compensatory capacity of the participants. On measures of tracking accuracy (mean error) the degree of difference between alcohol and nil alcohol performance (as indicated by effect size indices) were medium on the less difficult, and large on the more demanding tasks. Compensatory responding was however evident in the mean lag scores on those tasks in which the target motion is predictable. The very small or negative effect size index on measures of lag on two of the three preview tracking, and the fluid Non-preview Sine Tracking tasks is a function of compensation in some instances such that the lag became negative under alcohol (i.e. subject response preceded the target). While external reinforcers were minimised, desire to better personal or college performance may have been sufficient to enhance performance in this highly motivated and competitive population.

5.5.4. Gender

No alcohol compensatory response has been reported in respect of female subjects, whose performance worsens under placebo relative to nil alcohol baseline (Newlin, 1989). This apparent gender difference in compensatory responding under alcohol may be a factor in the failure of the present study to replicate the alcohol x time of day interaction found by Horne et al (1991) at 1300 and 1800 hours. The tendency for increased compensatory performance in males drinkers, may have been exaggerated in the present study by competition engendered by pre-existing cohort rivalries. The female subjects of the Horne et al (1991) studies were individually recruited, had no prior affiliation and no incentive to compete on performance measures.

5.6. Summary

Research specific to circadian mediation of alcohol related performance is sparse. Those studies which have examined the diurnal performance/alcohol interaction have typically used between groups design and limited the comparison to two time conditions (Jones, 1974; Horne ~~et al,~~ 1991; Horne ~~et~~ al, 1991). Reinberg (1992), in contrast, conducted a within groups repeated measures exploration of four time conditions, but with a sample of only six subjects examined under highly artificial hospital conditions. Existing literature lacks consensus around the specific types and duration of task more susceptible to diurnal performance fluctuations and alcohol x time of day interaction. The present study did not replicate results of previous work Jones (1974) and Reinberg (1992) in which significant alcohol x time of day interactions were found on brief psychomotor task performance. The two studies (Jones, 1974 and Reinberg, 1992) which isolated interactions using male subjects and brief tasks, each had large intervals (90 to 147 minutes) between onset of alcohol consumption and performance testing. While the exact nature of the alcohol consumption/time interval/diurnal performance variation interaction is unclear, one possible explanation is that as alcohol is metabolised across time, the fatigue inhibitory effects of high BAC (Smith et al, 1989-90) eventually give way to the fatigue additive effects of low BAC. Clearly further research is required to clarify the tasks, populations and conditions under which diurnal performance fluctuations and alcohol interact.

The findings of the present study indicate that while brief psychomotor tasks are highly susceptible to the performance inhibiting effects of alcohol at 2.26 ml/kg, they are less sensitive to diurnal performance fluctuations, or alcohol x time of day interactions. Absence of such effects in the present study is most likely to be due to the level of attention necessitated by the novelty, brevity and difficulty of the psychomotor tracking tasks used in performance assessment, in conjunction with competition in a highly motivated male subject group. As noted by Gale, Harphan and Lucus (1972) "It would appear that (time of day) effects are delicate plants which flourish only under certain critical conditions".

In supporting the null hypothesis with respect to time of day alcohol interaction, the findings of the current study contribute to a clearer understanding of the types of tasks, conditions and individual factors which are less susceptible to both circadian performance variation and alcohol/time of day interaction effects. Furthermore, this study has provided precise information as to the extent of the impact on driving related performance, produced by an alcohol dose of 2.26 ml/kg. A blood alcohol concentration approximating the legal limit for driving in New Zealand, has been found to produce significant deficits in driving related sensorimotor performance. Alcohol induced deficits in tracking performance were moderate to large (as indicated by effect size index), with accuracy declining as the level of task unpredictability increased. Similarly the effect of a 2.26 ml/kg dose of alcohol on reaction time was substantial.

The result of this study, coupled with the fatigue exacerbating of visual reaction speed produced by low alcohol dose (Smith et al, 1989-90), augur poorly for safe driving under alcohol. Driving related sensorimotor performance is significantly impaired at alcohol levels approximating the legal maximum for driving, and ironically may be subject to the additive effects of fatigue and alcohol if driving after alcohol-consumption is delayed to allow for BAC decline.

5.7. Suggested Direction for Future Research

Future research in the area of circadian variation in the extent to which alcohol impacts on driving related performance should consider alcohol relative to nil alcohol performance across several time conditions, day and night. The four time conditions used in the present study include two at times characterised by high (0900, 1800 hours), and two by low (1300 and 0100 hours), arousal levels (Anderson et al, 1991, Colquhoun in Webb, 1982). Use of a within groups repeated measures experimental design is essential due to the range of individual subject variables which independently influence alcohol effects and circadian rhythmicity. In the light of findings from the present study a longer, more monotonous psychomotor task may be more sensitive to both diurnal performance fluctuation and alcohol x time of day interaction than a battery of brief challenging sensorimotor tasks. It may be useful also to use a low alcohol dose to avoid the fatigue antagonistic effects described by Smith et al (1989-90).

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APPENDIX 1.

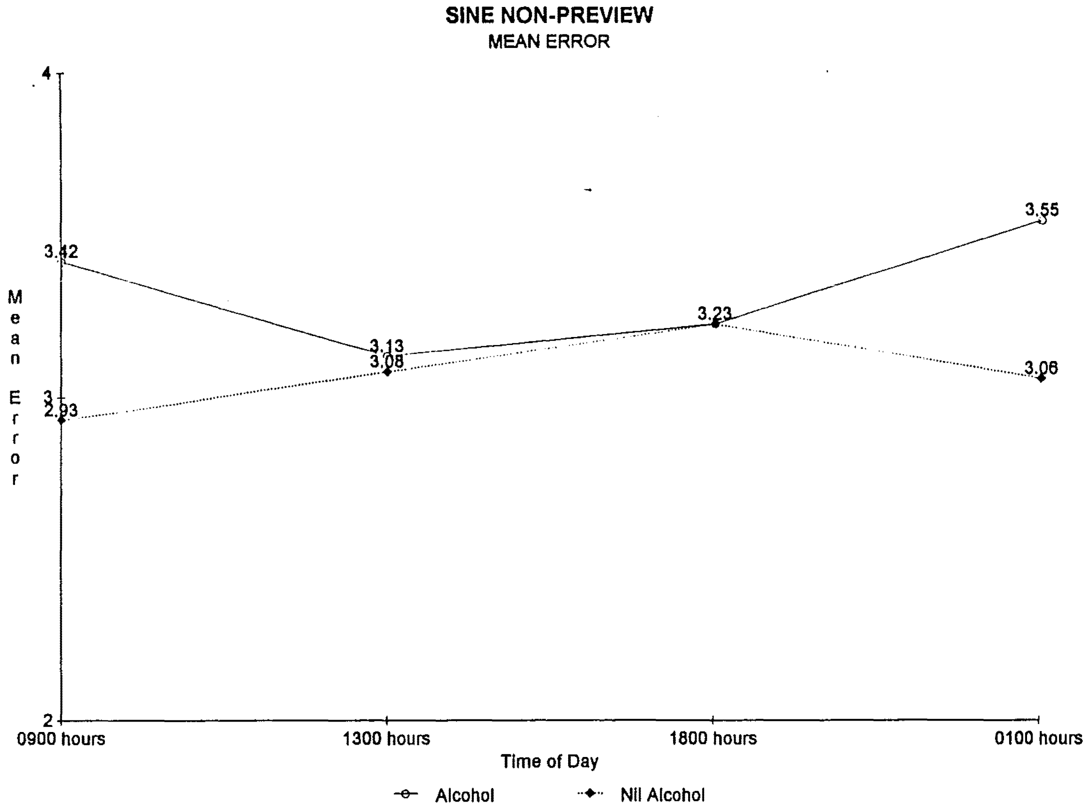

Figure 4. Group averaged mean error scores for alcohol and alcohol free tracking performance on Sine Non-preview at 0900, 1300, 1800 and 0100 hours.

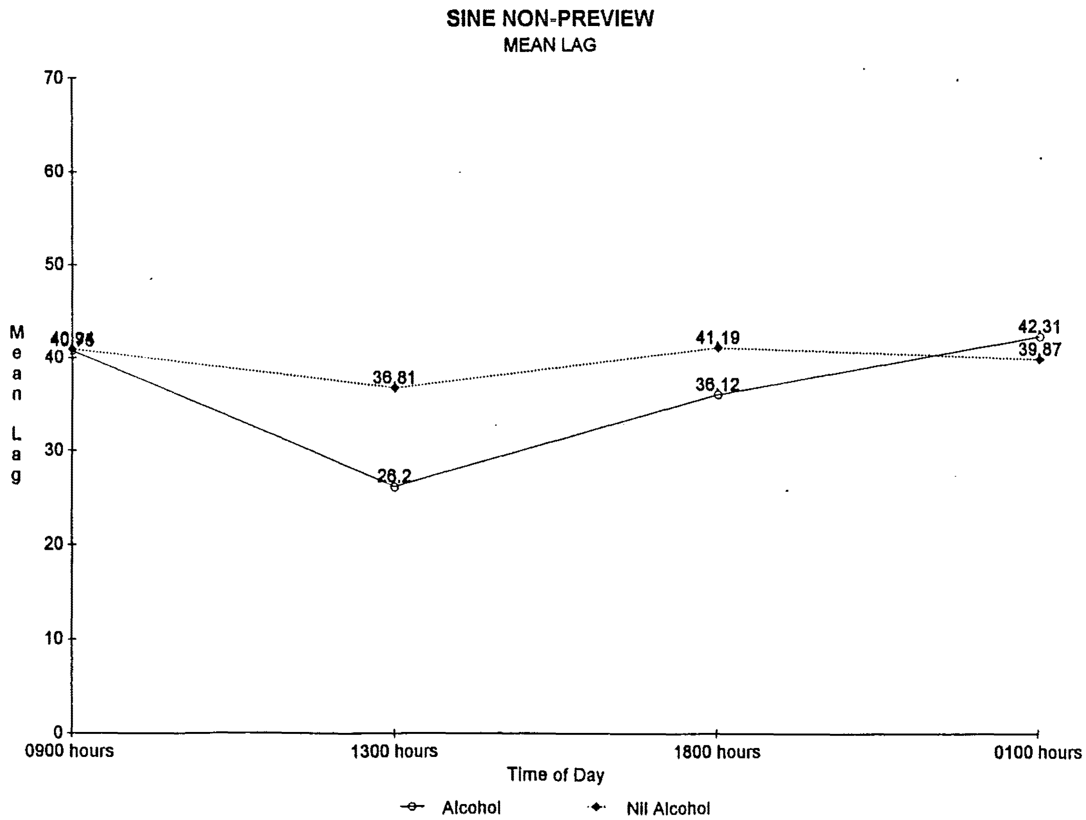

Figure 5. Group averaged mean lag scores for alcohol and alcohol free tracking performance on Sine Non-preview at 0900, 1300, 1800 and 0100 hours.

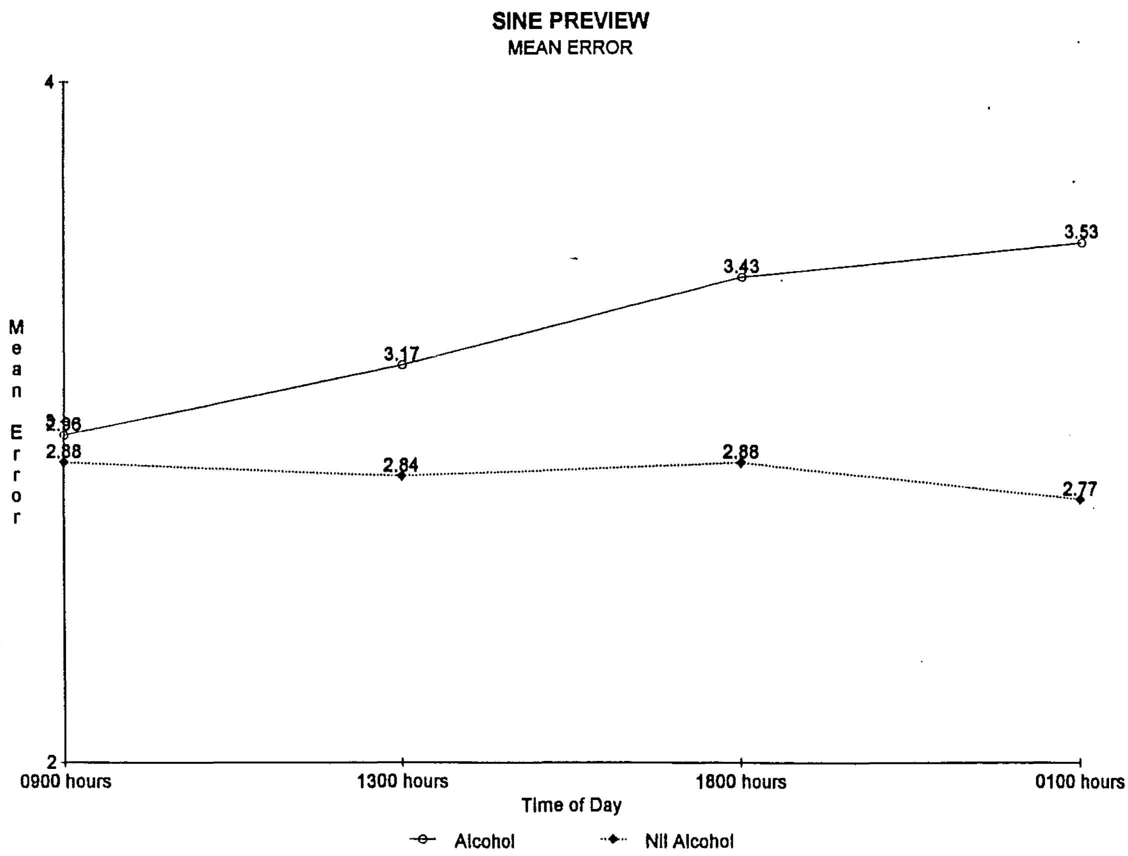

Figure 6. Group averaged mean error scores for alcohol and alcohol free tracking performance on Sine Preview at 0900, 1300, 1800 and 0100 hours.

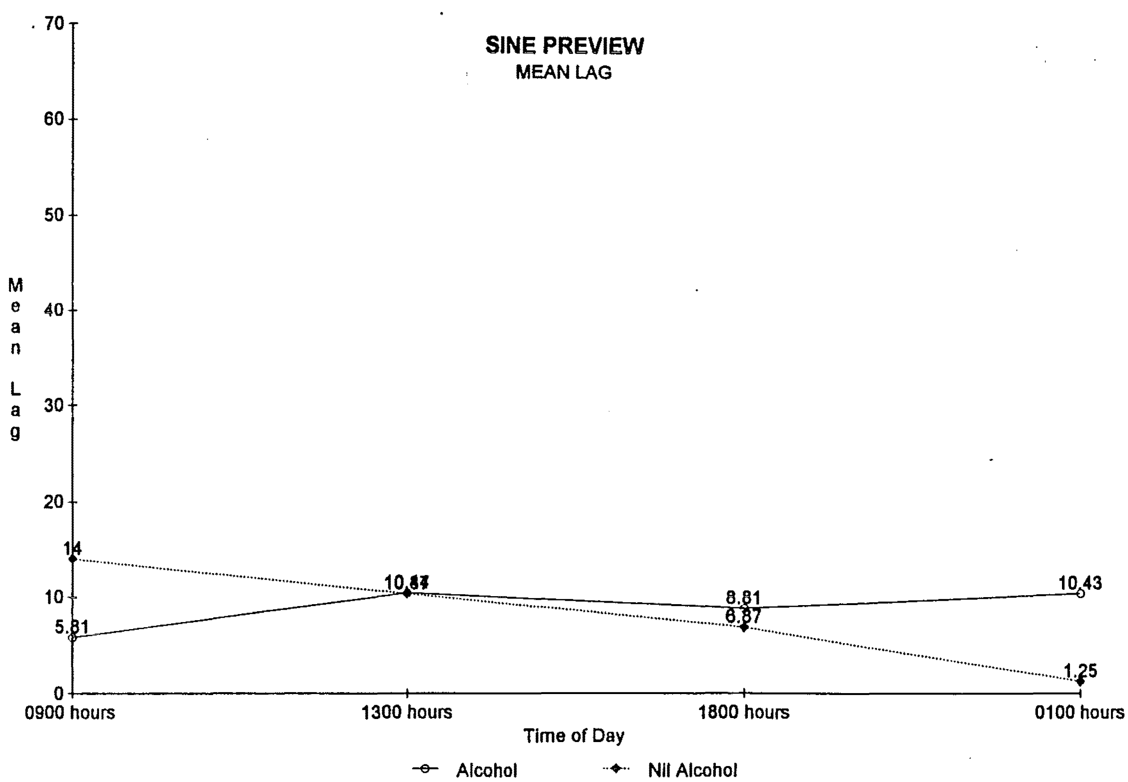

Figure 7. Group averaged mean lag scores for alcohol and alcohol free tracking performance on Sine Preview at 0900, 1300, 1800 and 0100 hours.

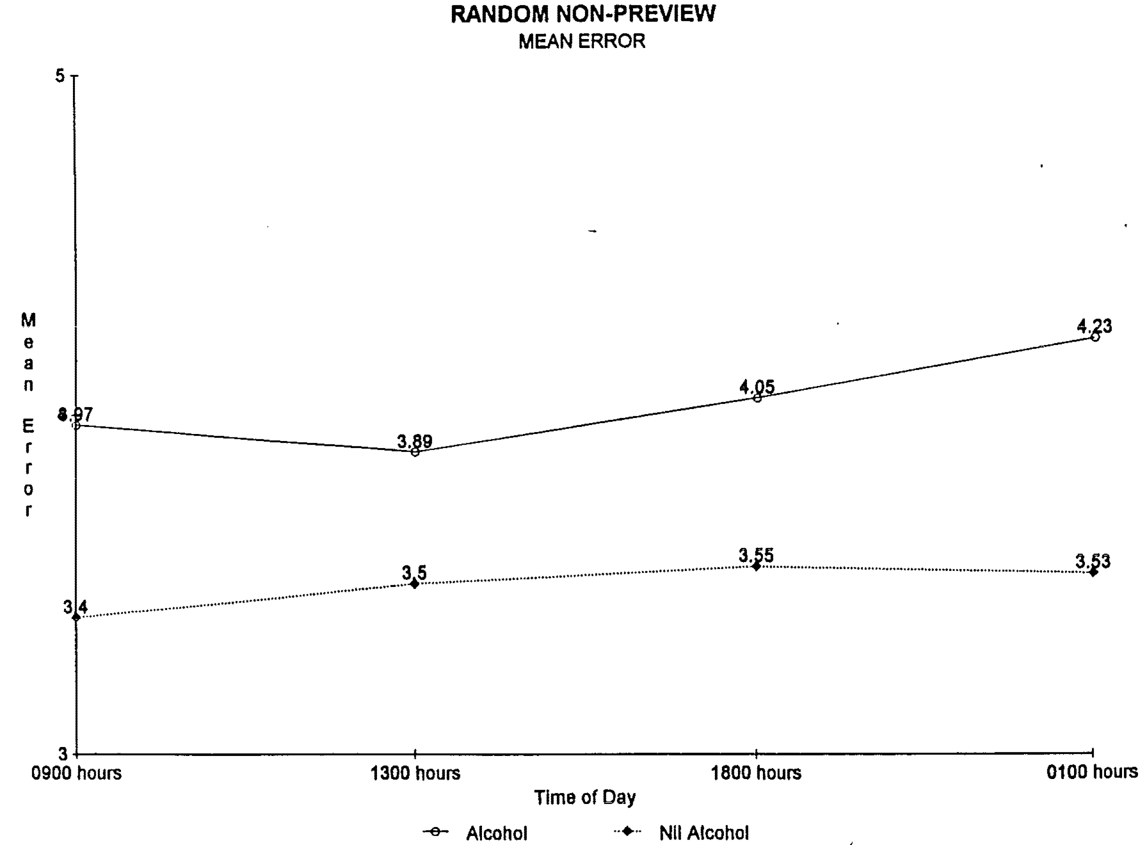

Figure 8. Group averaged mean error scores for alcohol and alcohol free tracking performance on Random Non-preview at 0900, 1300, 1800 and 0100 hours.

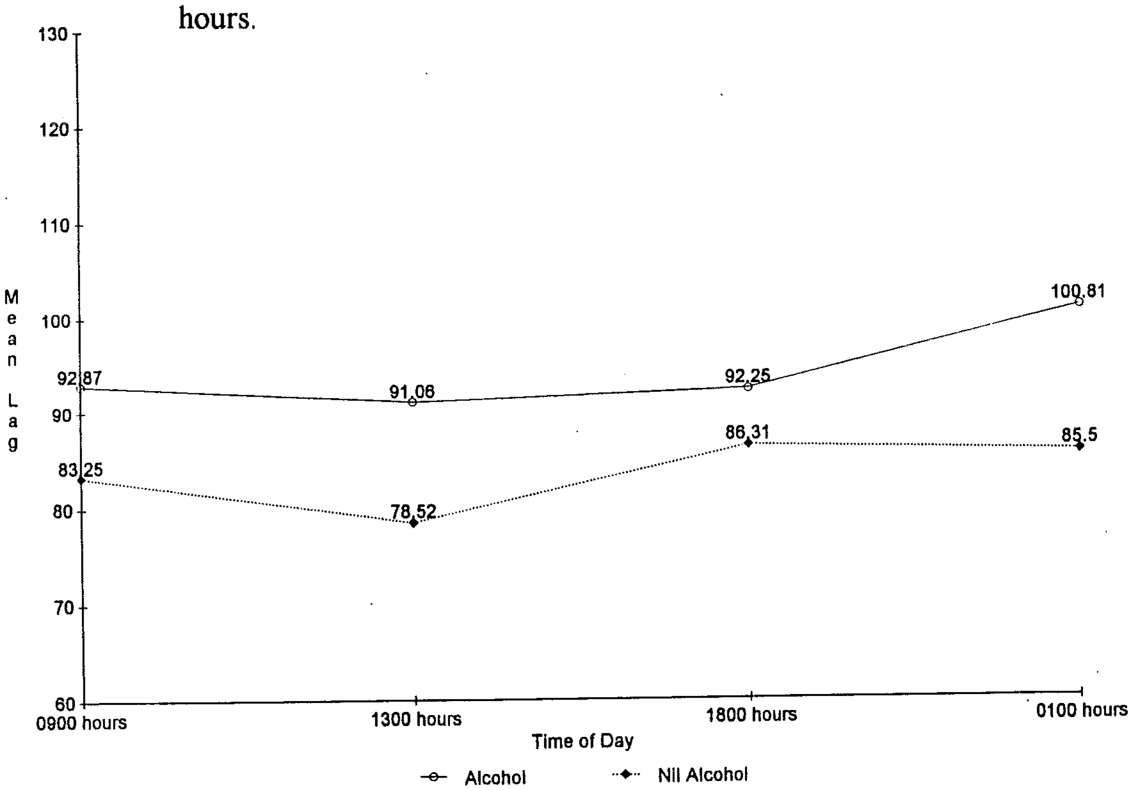

Figure 9. Group averaged mean lag scores for alcohol and alcohol free tracking performance on Random Non-preview at 0900, 1300, 1800 and 0100 hours.

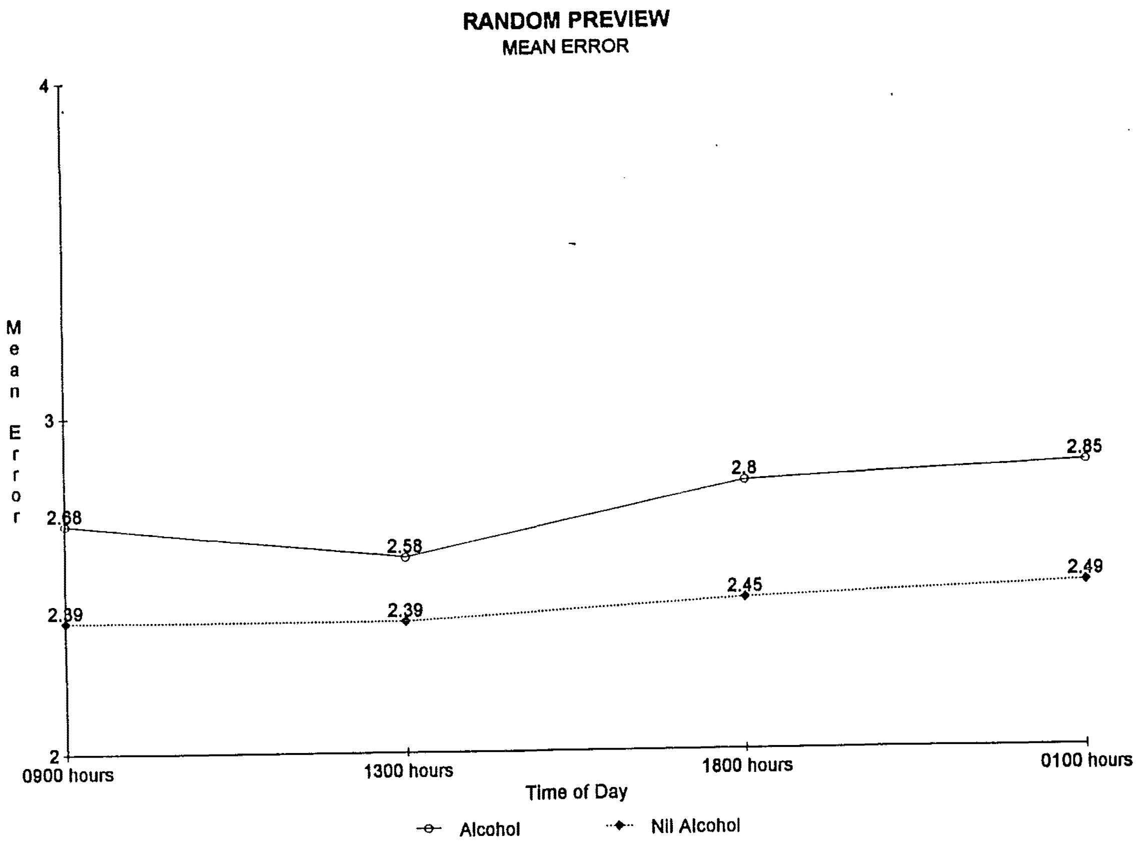

Figure 10. Group averaged mean error scores for alcohol and alcohol free tracking performance on Random Preview at 0900, 1300, 1800 and 0100 hours.

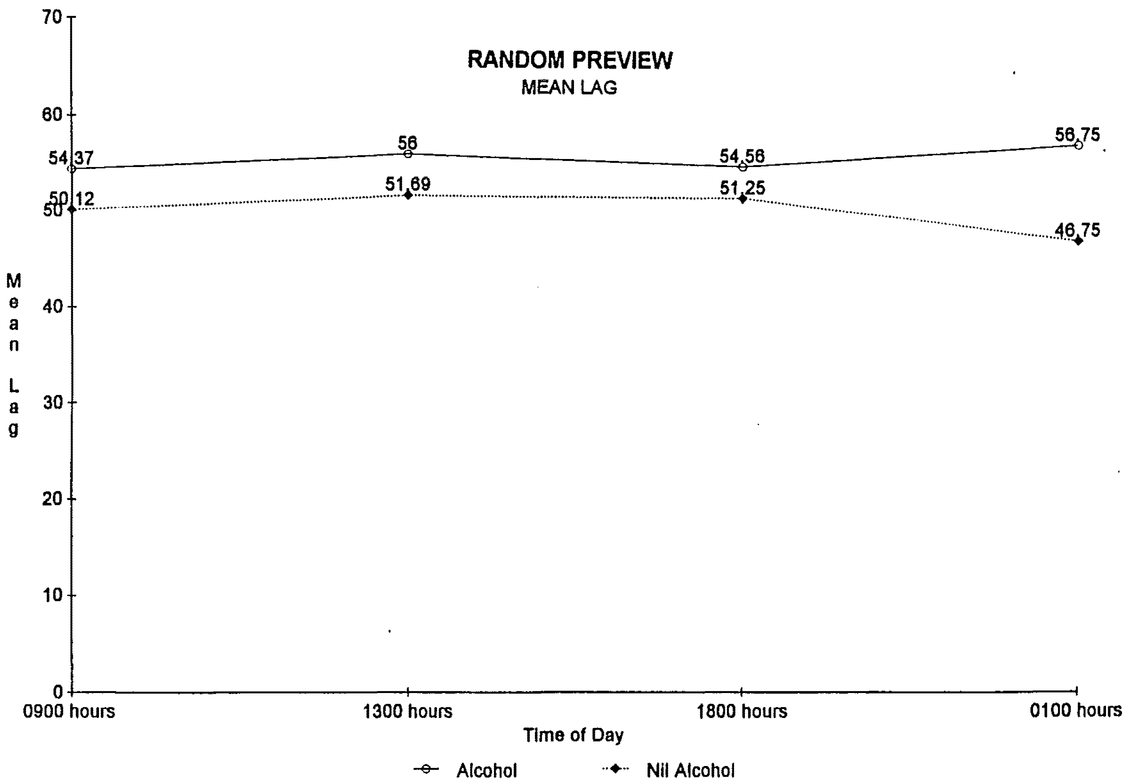

Figure 11. Group averaged mean lag scores for alcohol and alcohol free tracking performance on Random Preview at 0900, 1300, 1800 and 0100 hours.

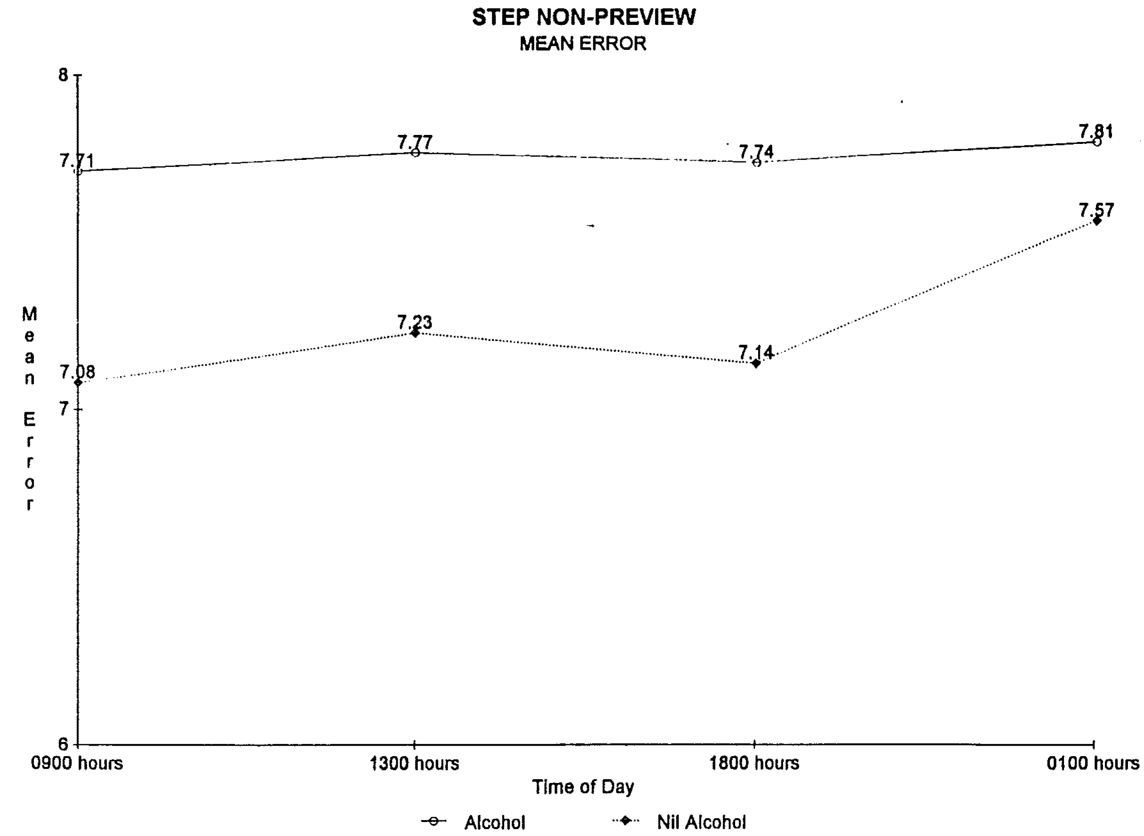

Figure 12. Group averaged mean error scores for alcohol and alcohol free tracking performance on Step Non-preview at 0900, 1300, 1800 and 0100 hours.

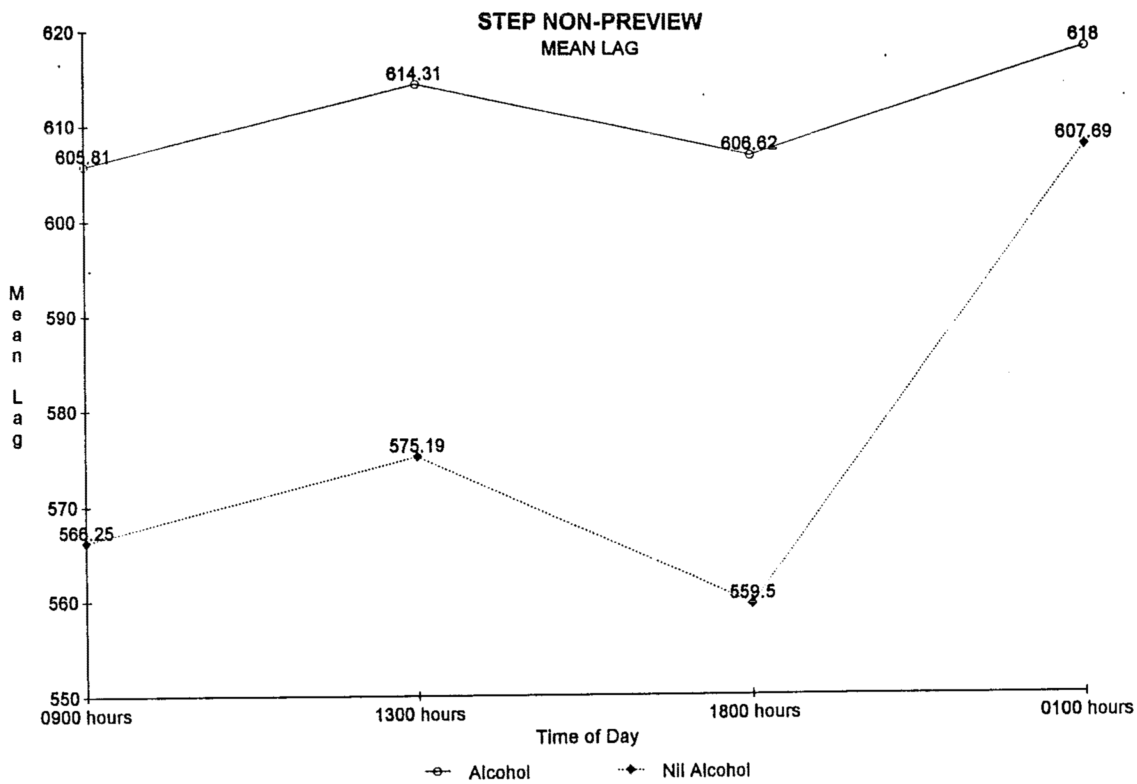

Figure 13. Group averaged mean lag scores for alcohol and alcohol free tracking performance on Step Non-preview at 0900, 1300, 1800 and 0100 hours.

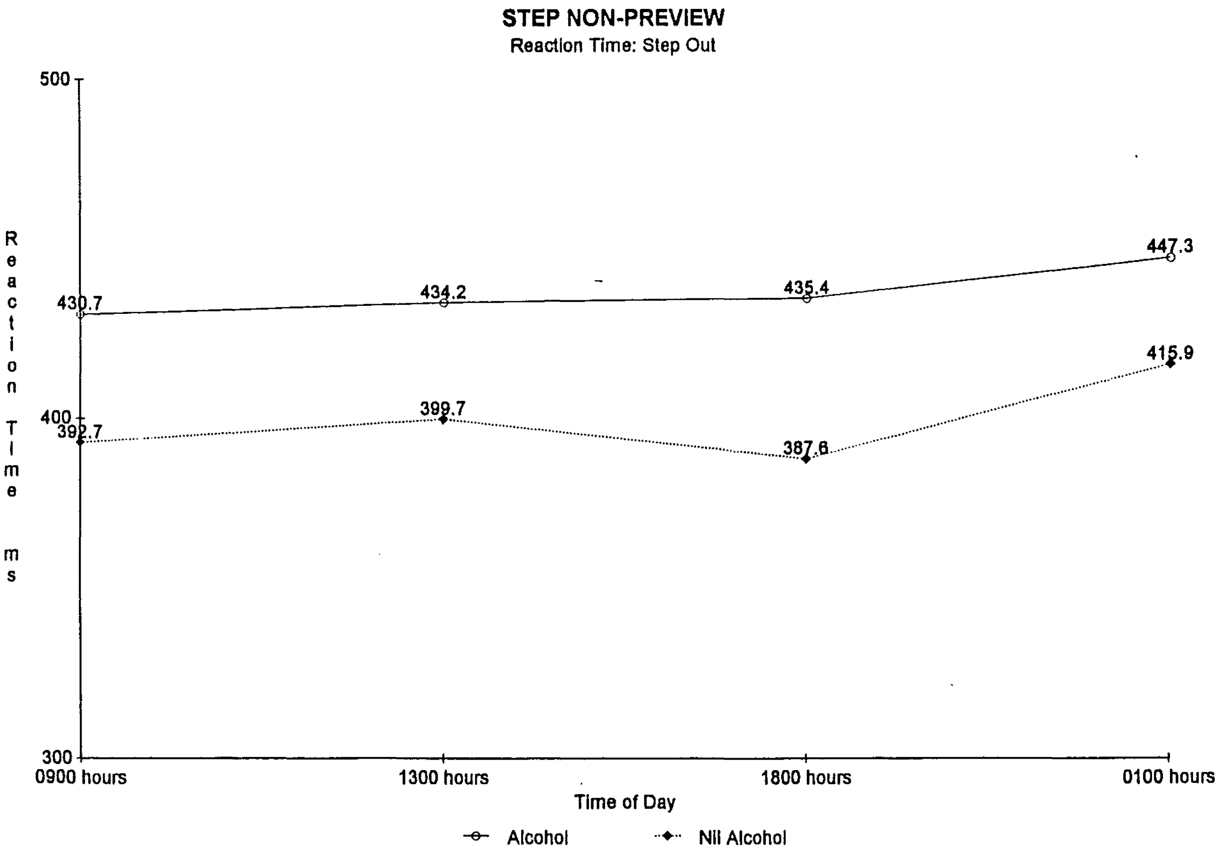

Figure 14. Group averaged "step out" reaction time for alcohol and alcohol free performance on Step Non-preview at 0900, 1300, 1800 and 0100 hours.

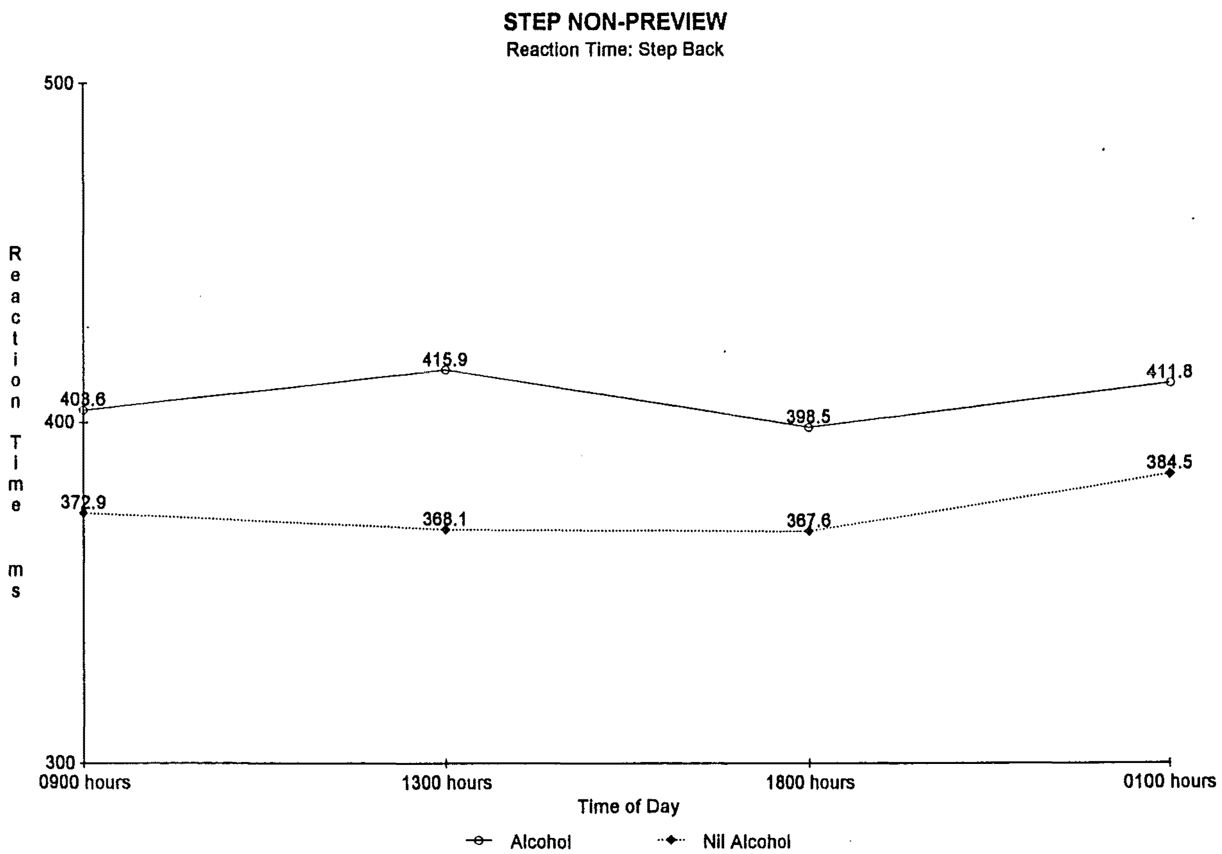

Figure 15. Group averaged "step back" reaction time for alcohol and alcohol free performance on Step Non-preview at 0900, 1300, 1800 and 0100 hours.

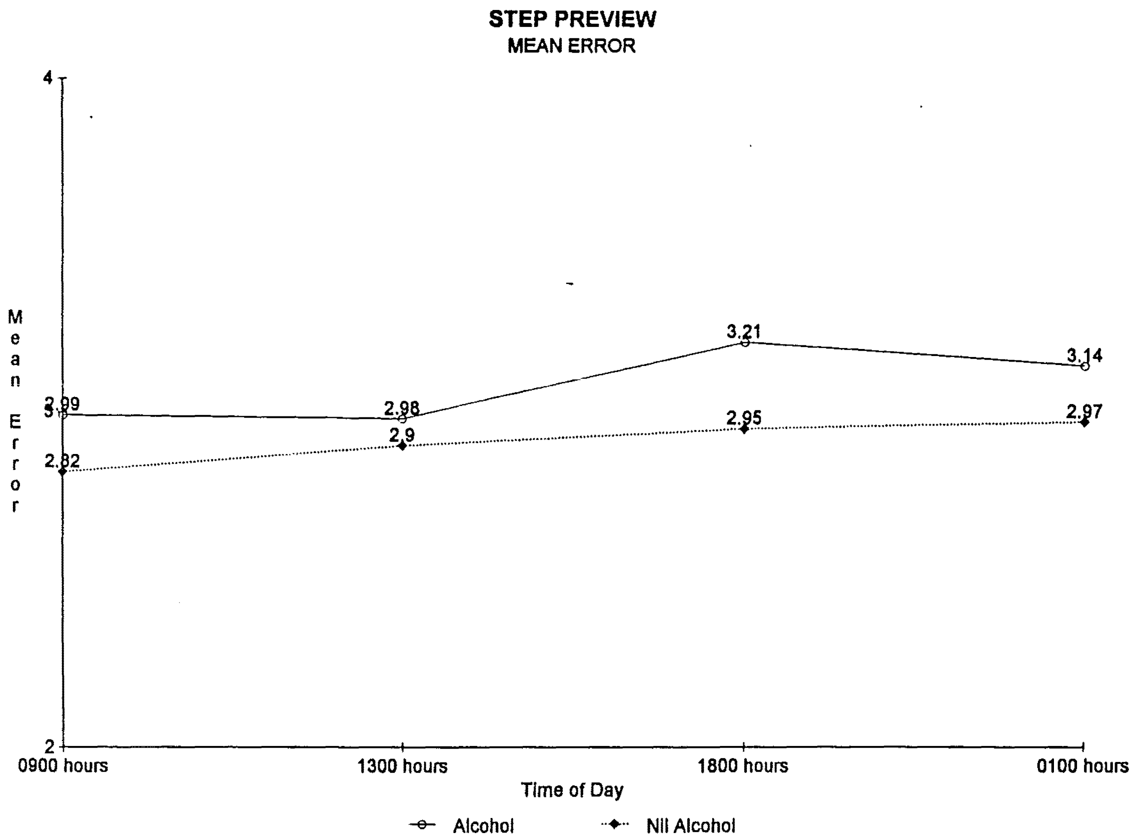

Figure 16. Group averaged mean error for alcohol and alcohol free tracking performance on Step Preview at 0900, 1300, 1800 and 0100 hours.

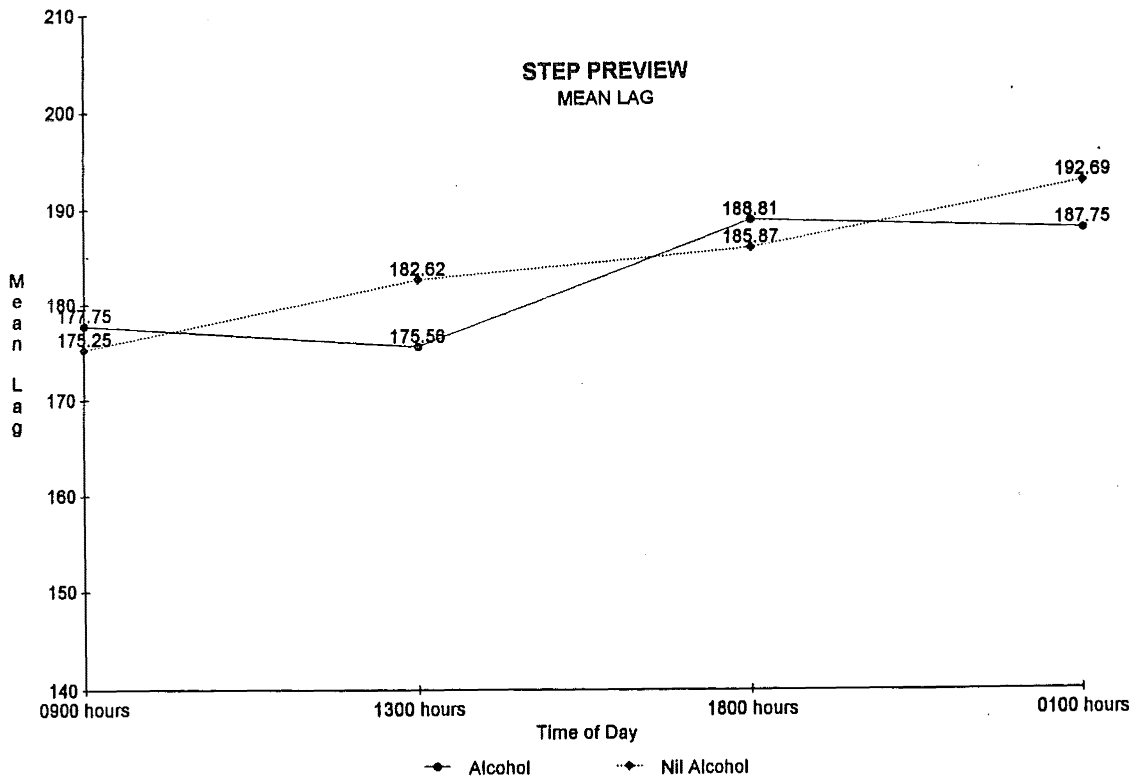

Figure 17. Group averaged mean lag for alcohol and alcohol free tracking performance on Step Preview at 0900, 1300, 1800 and 0100 hours.

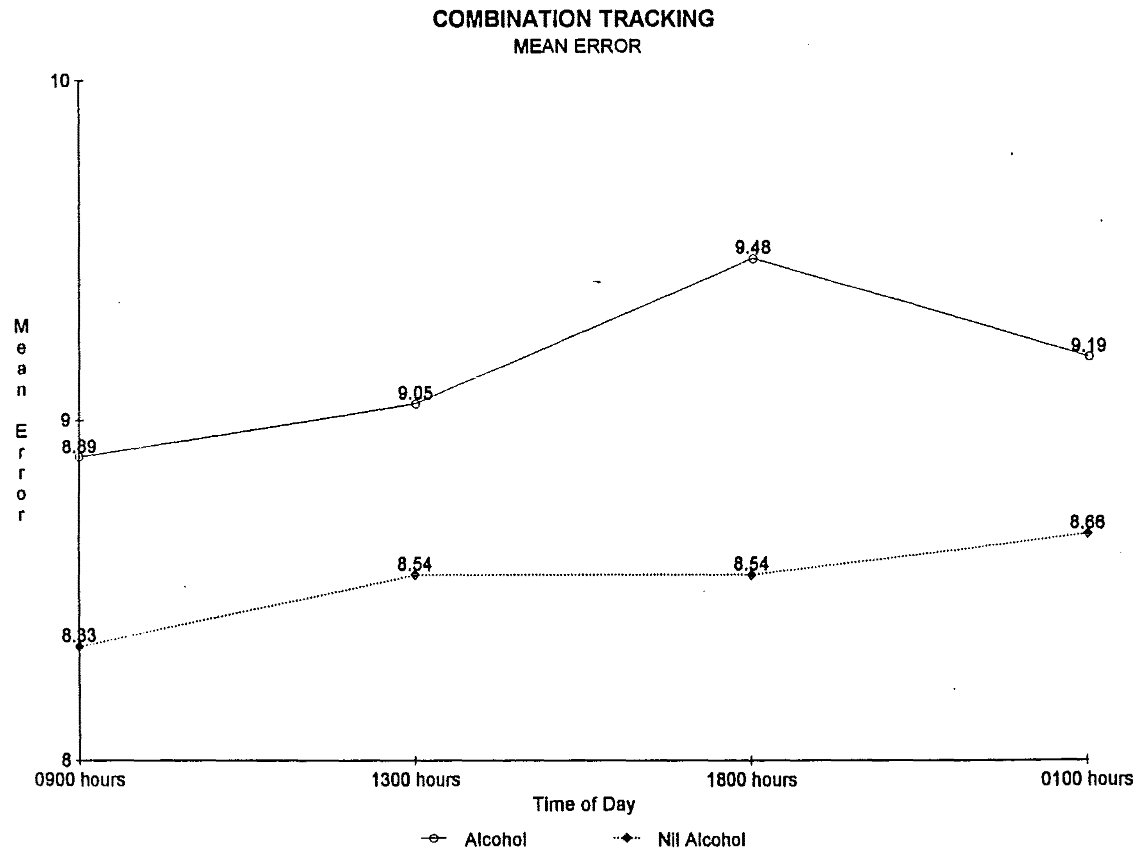

Figure 18. Group averaged mean error for alcohol and alcohol free tracking performance on Combination Tracking at 0900, 1300, 1800 and 0100 hours.

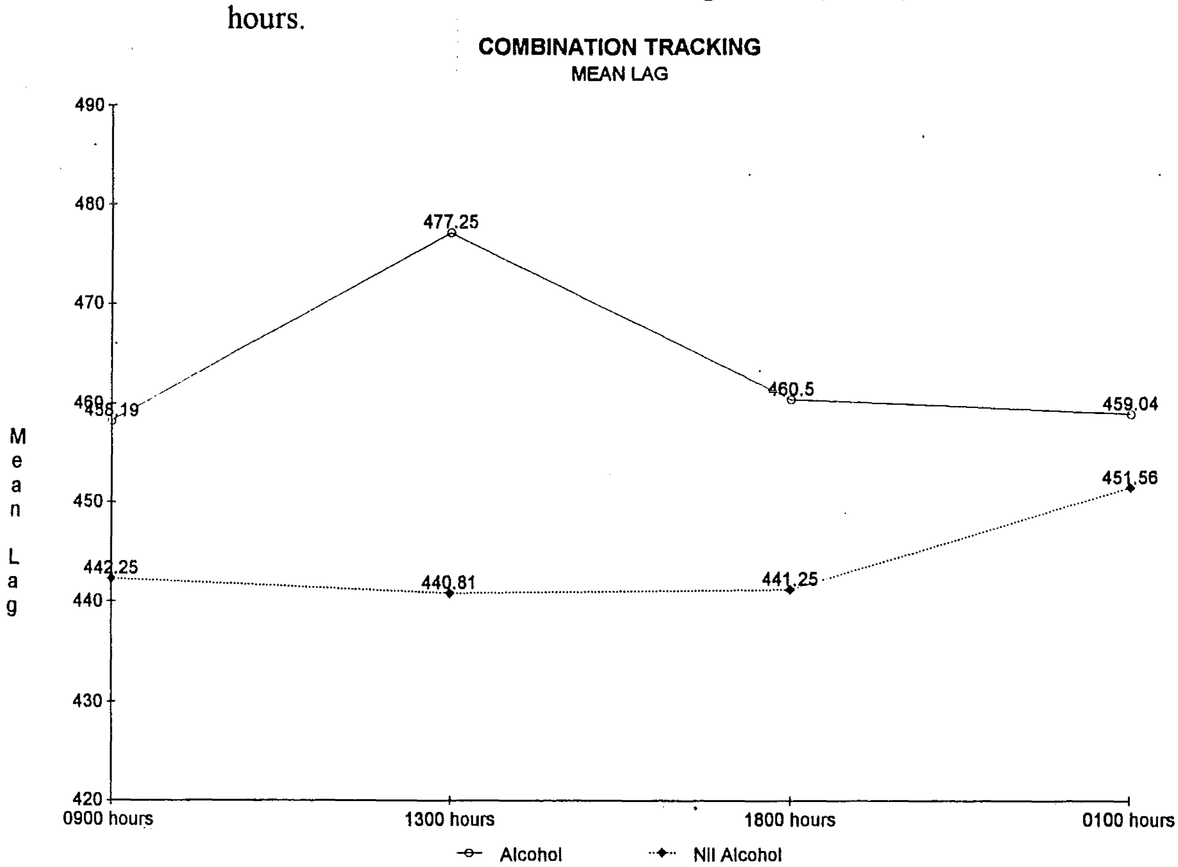

Figure 19. Group averaged mean lag for alcohol and alcohol free tracking performance on Combination Tracking at 0900, 1300, 1800 and 0100 hours.

APPENDIX 2.

Investigation into possible Circadian (daily) variation in the extent to which Alcohol affects driving related performance.

University of Canterbury, Department of Psychology

You are invited to participate as a subject in an investigation into possible daily variation in the extent to which alcohol effects driving related performance.

The aim of this project: The association between alcohol and impairment of driving related performance is well documented. The question with which this project is concerned is whether those effects are constant across time or variable depending on the time of day at which the alcohol was consumed.

If the effects of alcohol on driving performance are found to vary across time of day, drivers could be alerted to periods of increased susceptibility and adjust consumption or arrange alternative transport accordingly. Identification of high risk periods would also enable those responsible for administration of drink-drive legislation to concentrate resources at critical times when the impact of alcohol on driving is most pronounced. At the very least drivers and those involved in drink-drive education, legislation and law enforcement should be made aware that breath and/or blood alcohol concentration alone may not be a reliable indicator of the individuals capacity (or otherwise) to drive safely.

Time commitment involved: Your participation in this project would involve a commitment of two hours per week over five weeks. Testing sessions are scheduled across four specific times of day: 0900, 1300, 1800 and 0030 hours. Each participant will be tested at each of these four times, once with alcohol and once without (total of eight sessions). The alcohol free conditions form the baseline against which the effects of alcohol will be contrasted.

Procedure: Participants would be asked to arrive at each session with a nil breath alcohol concentration and to have been without food for the previous four hours. On arrival you will be breath tested, seated comfortably, then given a drink (Vodka and tonic at four and tonic alone at four sessions) and a filled roll. On each occasion you will be told whether or not the beverage is alcoholic. The whole process is expected to take about an hour. Participants who have consumed alcohol will be asked not to drive or engage in any hazardous activities for the next four hours.

The driving simulation task: The testing apparatus consists of a visual display unit, steering wheel and master computer. Each individual test is approximately two minutes long and requires the driver to steer an arrow head through a course displayed on a visual monitor while the master computer progressively calculates reaction speed and tracking accuracy. Each driver would be asked to complete six two-minute trials (with a brief rest between) at each session. The whole process is expected to take about an hour.

Alcohol quantity: The quantity of alcohol to be consumed at each session is 2.26 mls (37% alcohol) per kg of body weight, which should produce a breath alcohol concentration close to the legal limit for driving in New Zealand (400 micrograms of alcohol per litre of breath).

Preliminary data collection: Some preliminary information is required from prospective participants to ensure selection of a suitably balanced subject group. While we do need to keep a record of the results, the questionnaires themselves will be destroyed as soon as the information has been processed. All individual information, whether gathered during preliminary recruitment or throughout the actual investigation, will be identified by number code rather than subject name - the key to this code will be held in a secure place away from the data itself to ensure protection of individual identity.

Potential participants would be asked to:

1. Indicate the time of day at which they feel they perform at their best. A 19 item "Morningness-Eveningness" scale which takes about ten minutes to complete would ensure a balance of persons with morning and evening preferences.
2. Complete a 29 item "Internal-External Locus of Control Inventory" designed to give an indication of the extent to which participants consider situational and personal factors shape lives. This scale also takes about ten minutes to complete and has been included because variations in how people view the world have been associated with variations in how they respond to alcohol. Once again we are seeking a balance across our subject group.
3. Have their weight recorded to enable the appropriate quantity of alcohol to be calibrated.

Return on investment: At the end of the eight week testing programme each individual participant would receive feedback on his personal performance at each session. Including actual scores, the extent to which his performance varied across the four times of day independent of alcohol, and the extent to which performance varied under alcohol relative to alcohol free conditions.

Confidentiality of information: The results of the project may be published. But complete confidentiality of individual participants is assured. Material will be published only in terms of group averages and the identity of individual subjects withheld No one other than the participant himself will have access to individual scores or data collected at preliminary selection.

This project is being carried out by Anne Kerr (post-graduate student) in association with Dr Richard Jones of the Christchurch Hospital's Department of Medical Physics and Bioengineering and is supervised by Dr John Dalrymple-Alford of the Department of Psychology, University of Canterbury with funding assistance from the Alcohol Advisory Council of New Zealand. Anne can be contacted on (03) 3022871 and will be pleased to discuss any queries or concerns you may have about participation in the project.

Anne Kerr

CONSENT FORM

Investigation into possible Circadian (daily) variation in the extent to which alcohol affects driving related performance

I have read and understood the description of the above-named project. On this basis I agree to participate as a subject in the project, and I consent to publication of the results of the project with the understanding that anonymity will be preserved. I understand also that I may at any time withdraw from the project, including withdrawal of any information I have provided.

Signed ______________________ **Date** ________________

APPENDIX 3.

Horne and Ostberg "Morningness-Eveningness" Scale

INSTRUCTIONS:

1. Please read each question very carefully before answering.
2. Answer ALL questions.
3. Answer each question in numerical order.
4. Each question should be answered independently of others. Do NOT go back and check your answers.
5. All questions have a selection of answers. For each question place a cross alongside ONE answer only. Some questions have a scale instead of a selection of answers. Place a cross at the appropriate point along the scale.
6. Please answer each question as honestly as possible. Both your answers and the results will be kept, in strict confidence.
7. Please feel free to make any comments in the section provided below each question.

Name ______________________________

QUESTIONS

1. Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan your day?

AM 5 6 7 8 9 10 11 12

2. Considering only your own "feeling best" rhythm, at what time would you go to bed if you were entirely free to plan your evening?

PM 8 9 10 11 12 AM 1 2 3

3.	If there is a specific time at which you have to get up in the morning, to what extent are you dependent on being woken up by an alarm clock?	Not at all dependant Slightly dependent Fairly dependent Very dependant
4.	Assuming adequate environmental conditions, how easy do you find getting up in the mornings?	Not at all easy Not very easy Fairly easy Very easy
5.	How alert do you feel during the first half hour after having woken in the mornings?	Not at all alert Slightly alert Fairly alert Very alert
6.	How is your appetite during the first half-hour after having woken in the mornings?	Very poor Fairly poor Fairly good Very good
7.	During the first half-hour after having woken in the morning, how tired do you feel?	Very tired Fairly tired Fairly refreshed Very refreshed
8.	When you have no commitments the next day, at what time do you go to bed compared to your usual bedtime?	Seldom or never later Less than one hour later 1 - 2 hours later More than two hours later
9.	You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him is between 7-8 AM. Bearing in mind nothing else but your own "feeling best" rhythm. How do you think you would perform?	Would be on good form Would be on reasonable form Would find it difficult Would find it very difficult

10. At what time in the evening do you feel tired and as a result in need of sleep?

PM 8 9 10 11 12 AM 1 2 3

11. You wish to be at your peak performance for a test which you know is going to be mentally exhausting and lasting for two hours. You are entirely free to plan your day and considering only your own "feeling best" rhythm which ONE of the four testing times would you choose?

- 8.00 -10.00 AM
- 11.00 AM - 1.00 PM
- 3.00 - 5.00 PM
- 7.00 - 9.00 PM

12. If you went to bed at 11.00 PM at what level of tiredness would you be?

- Not at all tired
- A little tired
- Fairly tired
- Very tired

13. For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which ONE of these following events are you most likely to experience?

- Will wake up at usual time and NOT fall asleep.
- Will wake up at usual time and doze thereafter.
- Will wake up at usual time but fall asleep again
- Will NOT wake up until later than usual.

14. One night you have to remain awake between 4.00-6.00 AM in order to carry out a night watch. You have no commitments the next day. Which ONE of the following alternatives will suit you best?

- Would NOT go to bed until watch was over.
- Would take a nap before and sleep after.
- Would have a good sleep before and nap after.
- Would take ALL sleep before watch.

15. You have to do two hours of hard physical work. You are entirely free to plan your day and considering only your own "feeling best" rhythm which ONE of the following times would you choose?

- 8.00 - 10.00 AM
- 11.00 AM - 1.00 PM
- 3.00 - 5.00 PM
- 7.00 - 9.00 PM

You have decided to engage in hard physical exercise. A friend suggests that you do this for one hour twice a week and the best time for him is between 10.00-11.00 PM. Bearing in mind nothing else but your own "feeling best" rhythm how well do you think you would perform?

Would be on good form ☐
Would be on reasonable form ☐
Would find it difficult ☐
Would find it very difficult ☐

Suppose that you can choose your own work hours. Assume that you worked a FIVE hour day (including breaks) and that your job was interesting and paid by results. Which FIVE CONSECUTIVE HOURS would you select?

12	1	2	3	4	5	6	7	8	9	10	11	**12**	1	2	3	4	5	6	7	8	9	10	11	**12**

Midnight Noon Midnight

8. At what time of the day do you think you reach your "feeling best" peak?

12	1	2	3	4	5	6	7	8	9	10	11	**12**	1	2	3	4	5	6	7	8	9	10	11	**12**

Midnight Noon Midnight

19. One hears about "morning" and "evening types of people. Which ONE of these types do you consider yourself to be?

Definitely a "morning" type ☐
Rather more a "morning" than an "evening" type. ☐
Rather more an "evening" than a "morning" type. ☐
Definitely an "evening" type. ☐

Reference

Horne, J. A. & Ostberg, O. (1976) A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. International Journal of Chronobiology Vol. 4, 97-110.

APPENDIX 4.

Rotter Internal-External Locus of Control Scale

Social Reaction Inventory

This is a questionnaire to find out the way in which certain important events in our society affect different people. Each item consists of a pair of alternative lettered ***a*** or ***b***. Please select the one statement of each pair (and only one) which you more strongly ***believe*** to be the case as farm as you're concerned. Be sure to select the one you actually believe to be more true rather than the one you think you should choose or the one you would like to be true. This is a measure of personal belief, obviously there are no right or wrong answers.

Your answer, either ***a*** or ***b*** to each question on this inventory, is to be reported beside the question. Print your name in the space below before handing in the completed questionnaire

Please answer these items ***carefully*** but do not spend too much time on any one item. Be sure to find an answer for ***every*** choice. For each numbered question make a X on the line beside either the ***a*** or ***b***, whichever you choose as the statement most true.

In some instances you may discover that you believe both statements or neither one. In such cases, be sure to select the one you more strongly believe to be the case as far as you're concerned. Also try to respond to each item ***independently*** when making your choice; do no be influenced by your previous choices.

Name: ____

Remember - Select that alternative which you personally believe to be more true.

I more strongly believe that:

1. _____ a. Children get into trouble because their parents punish them too much.
   _____ b. The trouble with most children nowadays is that their parents are too easy with them.

2. _____ a. Many of the unhappy things in people's lives are partly due to bad luck.
   _____ b. People's misfortunes result from the mistakes they make.

3. _____ a. One of the major reasons why we have wars is because people don't take enough interest in politics.
_____ b. There will always be war no matter how hard people try to prevent it.

4. _____ a. In the long run people get the respect they deserve in this world.
_____ b. Unfortunately, an individual's worth often passes unrecognized no matter how hard he tries.

5. _____ a. The idea that teachers are unfair to students is nonsense.
_____ b. Most students don't realize the extent to which their grades are influenced by accidental happenings.

6. _____ a. Without the right breaks one cannot be an effective leader.
_____ b. Capable people who fail to become leaders have not taken advantage of their opportunities.

7. _____ a. No matter how had you try some people just don't like you.
_____ b. People who can't get others to like them don't understand how to get along with others.

8. _____ a. Heredity plays the major role in determining one's personality.
_____ b. It is one's experiences in life which determine what they're like.

9. _____ a. I have often found that what is going to happen will happen.
_____ b. Trusting to fate has never turned out as well for me as making a decision to take a definite course of action.

10. _____ a. In the case of the well prepared student there is rarely if ever such a thing as an unfair test.
_____ b. Many times exam questions tend to be so unrelated to course work that studying is really useless.

11. _____ a. Becoming a success is a matter of hard work, luck has little or nothing to do with it.
_____ b. Getting a good job depends mainly on being in the right place at the right time.

12. _____ a. The average citizen can have an influence in government decisions.
_____ b. This world is run by the few people in power, and there is not much the little guy can do about it.

13. _____ a. When I make plans, I am almost certain that I can make them work.
_____ b. It is not always wise to plan too far ahead because many things turn out to be a matter of good or bad fortune anyhow.

14. _____ a. There are certain people who are just no good.
_____ b. There is some good in everybody.

15. _____ a. In my case getting what I want has little or nothing to do with luck.
_____ b. Many times we might just as well decide what to do by flipping a coin.

16. _____ a. Who gets to be the boss often depends on who was lucky enough to be in the right place first.
_____ b. Getting people to do the right thing depends upon ability: luck has little or nothing to do with it.

17. _____ a. As far a s world affairs are concerned, most of us are the victims of forces we can neither understand, nor control.
_____ b. By taking an active part in political and social affairs the people can control world events.

18. _____ a. Most people can't realize the extent to which their lives ar controlled by accidental happenings.
_____ b. There really is no such thing as "luck".

19. _____ a. One should always be willing to admit his mistakes.
_____ b. It is usually best to cover up one's mistakes.

20. _____ a. It is hard to know whether or not a person really likes you.
_____ b. How many friends you have depends upon how nice a person you are.

21. _____ a. In the long run the bad things that happen to us are balanced by the good ones.
_____ b. Most misfortunes are the result of lack of ability, ignorance, laziness or all three.

22. _____ a. With enough effort we can wipe out political corruption.
_____ b. It is difficult for people to have much control over the things politicians do in office.

23. _____ a. Sometimes I can't understand how teachers arrive at the grades they give.
_____ b. There is a direct connection between how hard I study and the grades I get.

24. _____ a. A good leader expects people to decide for themselves what they should do.
_____ b. A good leader makes it clear to everybody what their jobs are.

25. _____ a. Many times I feel that I have little influence over the things that happen to me.
_____ b. It is impossible for me to believe that chance or luck plays an important role in my life.

26. _____ a. People are lonely because they don't try to be friendly.
_____ b. There's not much use in trying too hard to please people, if they like you, they like you.

27. _____ a. There is too much emphasis on athletics in high school.
_____ b. Team sports are an excellent way to build character.

28. _____ a. What happens to me is my own doing.
_____ b. Sometimes I feel that I don't have enough control over the direction my life is taking.

29. _____ a. Most of the time I can't understand why politicians behave the way they do.
_____ b. In the long run people are responsible for bad government on a national as well as on a local level.

Reference

Lefcourt, H. M. (1976) Locus of Control: Current trends in theory and research. Sydney: John Wiley & Sons